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POULTRY HUSBANDRY

MORLEY A. JULL

Professor and Head of Poultry Department
University of Maryland
College Park, Md.

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POULTRY HUSBANDRY

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PREFACE

The purpose of this book is to convey to its readers some conception of the relative importance of the poultry industry as a branch of agriculture, the fundamental principles involved in various poultry practices, and up-to-date information concerning methods of poultry production. The more important economic factors in producing and marketing poultry products are given due consideration.

Success in poultry raising depends largely upon one's knowledge of the business and one's ability to produce and market poultry and poultry products efficiently. Fundamental principles must be understood to some extent at least before the most economical methods can be practiced intelligently. For this reason the major aspects of poultry production and marketing are discussed, first, with respect to principles involved and, second, with respect to practices to be followed.

This book is an attempt to integrate the facts of modern science for the benefit of students of poultry husbandry and practical poultrymen. The preparation of the book has been inspired in the spirit of rendering the greatest possible service to the poultry industry.

The author is deeply indebted to the following staff members of the Poultry Department of the University of Maryland for reading the portions of the book indicated and making valuable suggestions which were incorporated in the text. Dr. Mary Juhn read the entire text. Dr. J. M Gwin, Chapters 12 and 13; Dr. C. S. Shaffner, Chapters 3, 4, and 5; and Dr. G. F. Combs, Chapters 9 and 10. Dr. R. M. Fraps of the U.S Agricultural Research Center made a significant contribution with respect to the endocrine regulatory system and its functioning.

MORLEY A. JULL

UNIVERSITY OF MARYLAND
COLLEGE PARK, MD.
January, 1951

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CHAPTER 1

THE POULTRY INDUSTRY

The poultry industry serves a very important part in converting grains and other products into eggs and poultry meat for the nutritional benefit of mankind. Providing consumers with food products of superior quality as economically as possible and at reasonable cost is the chief responsibility of agriculture. The poultry industry, in its position as a branch of agriculture, has increased in importance during recent years as a supplier of these products.

Food for humans is of plant and animal origin, certain proportions of plant and of animal products being necessary to provide properly balanced diets for all classes of people. Foods of animal origin provide certain nutrients in which many plant products are more or less deficient. Of particular importance in providing well-balanced diets for growing children, housewives, farmers, industrial workers, and those engaged in sedentary occupations are milk, eggs, red meats, and poultry meat of various kinds.

Whereas foods of plant origin, if consumed in sufficient quantity, provide humans with plenty of energy, foods of animal origin have a higher nutritional value because of their supplies of proteins, minerals, and vitamins in addition to the energy they provide. Grains and most other plant products are relatively low in protein; but milk, eggs, and meat of various kinds have a higher level of protein and contain certain amino acids lacking in plant foods. Amino acids are the nutrients comprising the proteins, several amino acids being very important in human nutrition. Foods of animal origin also supply humans with more of certain minerals and vitamins than do foods of plant origin.

Relative Efficiency of Animal Food Production. Since cows, swine, sheep, beef cattle, and poultry are the most important food-producing classes of livestock of this country, it is interesting to compare their relative efficiencies in converting feed into food. From the standpoint of proteins, minerals, and vitamins, milk production is the highest in the efficiency of production. Egg production ranks second in efficiency. Pork production, considering the relative amount of fat produced, apparently ranks third. Chicken, duck, goose, and turkey meat production rank above beef and lamb production in efficiency, although beef

cattle and sheep utilize forage crops to a greater extent than the various classes of poultry mentioned except geese.

Relative Importance of Poultry Production. The gross poultry income as a percentage of the gross farm income during each of the following 3-year periods was:

1916 to 1918	1925 to 1927	1934 to 1936	1943 to 1945
8.43	11.19	11.57	13.25

The gross poultry income as a percentage of the gross income from livestock and livestock products during each of the following 3-year periods was:

1916 to 1918	1925 to 1927	1934 to 1936	1943 to 1945
17.52	20.74	20.18	23.16

For more than a quarter of a century, the relative importance of the poultry industry has steadily increased. At least two reasons are responsible: (1) the relative efficiency of poultry in converting feed into food for humans; (2) the fact that poultry production is not only a farm enterprise that uses relatively inexpensive labor and provides considerable quantities of eggs and meat for home use in addition to products sold but also because there has been considerable commercial expansion of the industry. In 1945 there were 4,900,948 farms on which chickens were reported, this number representing 85.6 per cent of all farms in the United States.

Relative Importance of Species of Poultry. The various species of poultry that contribute toward the total poultry income include chickens, turkeys, ducks, geese, guineas, pigeons, and others of less significance. The data in Table 1 show that chickens have been responsible for 91 per cent of the total annual poultry income.

TABLE 1. PERCENTAGE OF TOTAL GROSS POULTRY INCOME CONTRIBUTED BY EACH BRANCH OF THE POULTRY INDUSTRY IN 1939 AND 1945

	1939	1945
Gross egg income	48.8	54.1
Gross farm-raised chicken income	42.2[a]	27.3
Gross broiler income	[a]	9.6
Gross turkey income	7.4	7.8
Gross duck, goose, guinea, etc., income	1.6	1.2
Total	100.0	100.0

[a] If any broiler income was reported in 1939, it was included with the gross income from farm-raised chickens.

It is because chickens constitute such a relatively important source of the total poultry income obtained by poultry producers that this book is devoted entirely to problems of producing and marketing chickens and chicken eggs. Problems of raising and marketing other species are discussed in "Raising Turkeys, Ducks, Geese, and Game Birds."

Relative Importance of Branches of the Chicken Industry. During 1945 to 1947, the average annual gross income obtained from eggs, farm-raised chickens, and commercial broilers was $2,955,284,000. Eggs contributed 62.5 per cent of this income; farm-raised chickens contributed 27.8 per cent; commercial broilers contributed 9.7 per cent. During 1945 to 1947 the gross income from commercial broilers amounted to about 26 per cent of the gross income from farm-raised chickens and commercial broilers.

EGG AND FARM CHICKEN PRODUCTION

The chicken industry in the United States has attained its present position of great economic importance as a result of steady growth, as shown in Figs. 1 and 2, except for a decline during the depression period

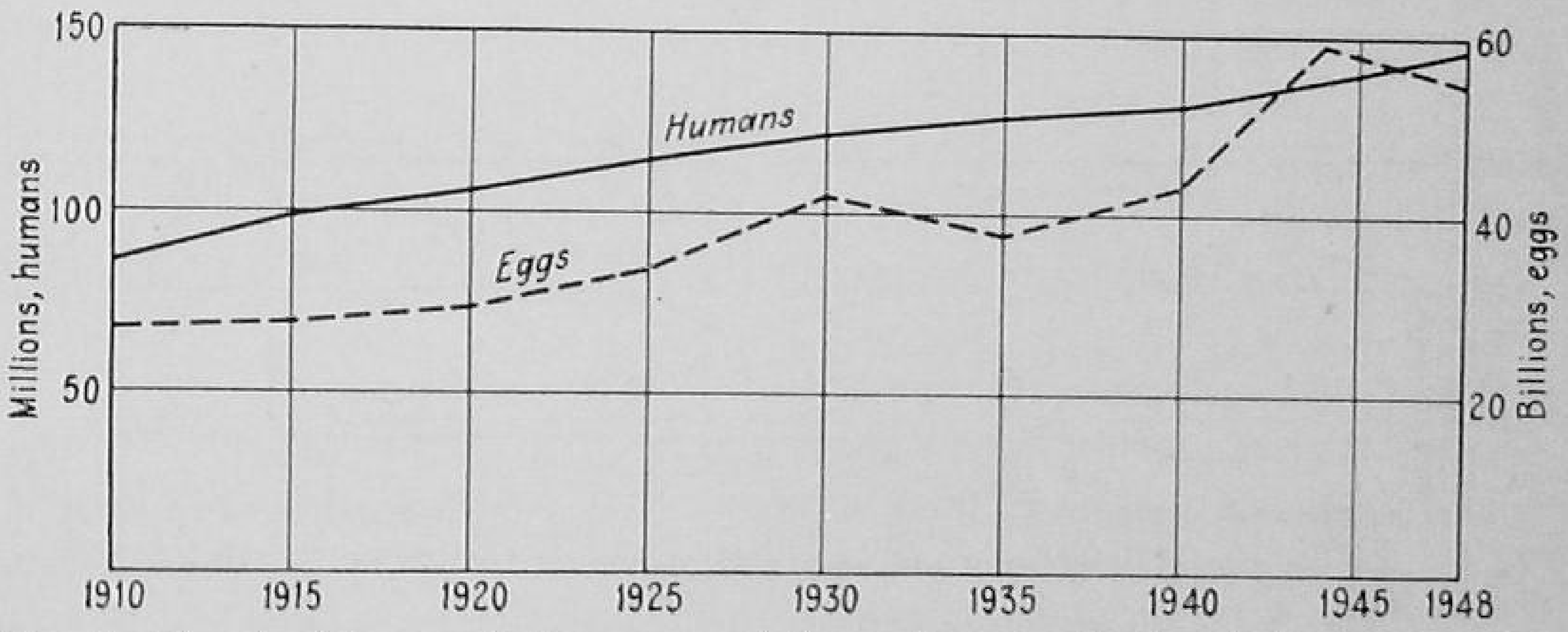

FIG. 1. Trends of increase in human population and egg production, United States, 1910 to 1948.

and a stimulus during the Second World War, because of the great demand for eggs and chicken meat.

Figure 1 shows the trends of increase in human population and egg production in the United States from 1910 to 1948. From 1925 to 1930, a period of relative prosperity, egg production increased relatively faster than the rate of increase of the human population; but from 1930 to 1935, the depression period with relatively low family incomes, egg production decreased both relatively and absolutely in relation to the human population trend. Unless unforeseen factors affect the human population trend, it is apparent that there will be a demand for increased egg production, especially if per capita consumption remains relatively high.

Although chickens are kept on most farms in practically all sections of the United States, the most heavily populated sections are in certain areas of the Northeastern states, throughout the Middle West, and in limited areas in the Pacific Coast states, as shown in Fig. 3.

Eggs are produced in great numbers on commercial-poultry farms located in the Northeastern and Pacific Coast states and in some sections of the Middle West states. At the same time, the very large number of general-farm flocks throughout these regions and in Southern states accounts for the major share of the total egg production.

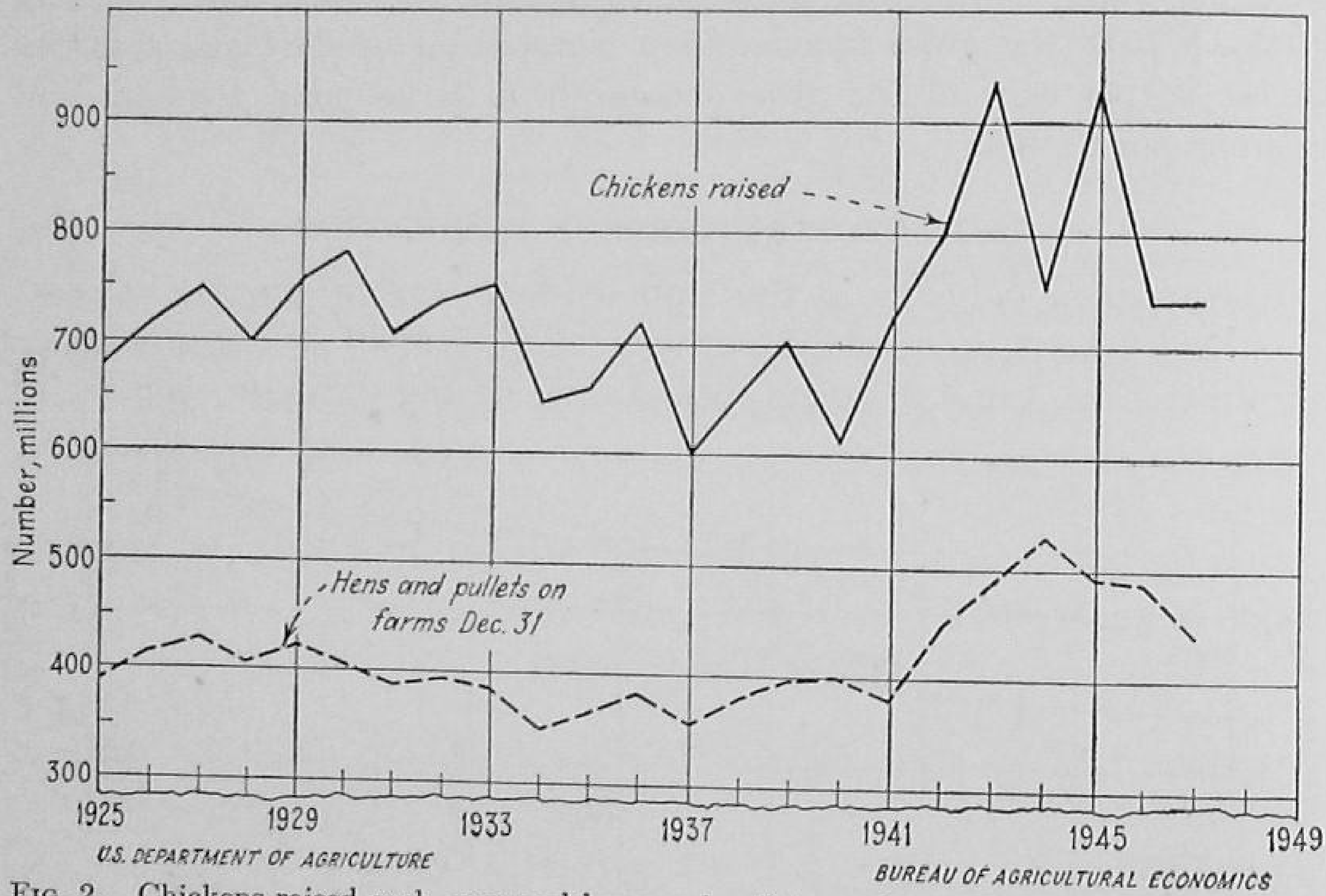

FIG. 2. Chickens raised each year and hens and pullets on farms Dec. 31, United States, 1925 to 1947.

The number of chickens raised each year follows the same general pattern as that for eggs produced, except that in certain localized areas in some of the states commercial-broiler production is highly concentrated, as indicated by the concentration of black dots in Fig. 4.

The Leading Egg- and Farm-chicken-producing States. Although poultry raising is carried on in all parts of the country, 15 states are responsible for more than one-half of the eggs produced each year and 15 states are responsible for more than one-half of the farm-raised chickens produced each year.

Table 2 gives the rank of the first 15 states with respect to egg production, 1942 to 1946, and the rank of the first 15 states with respect to gross egg income, 1942 to 1946.

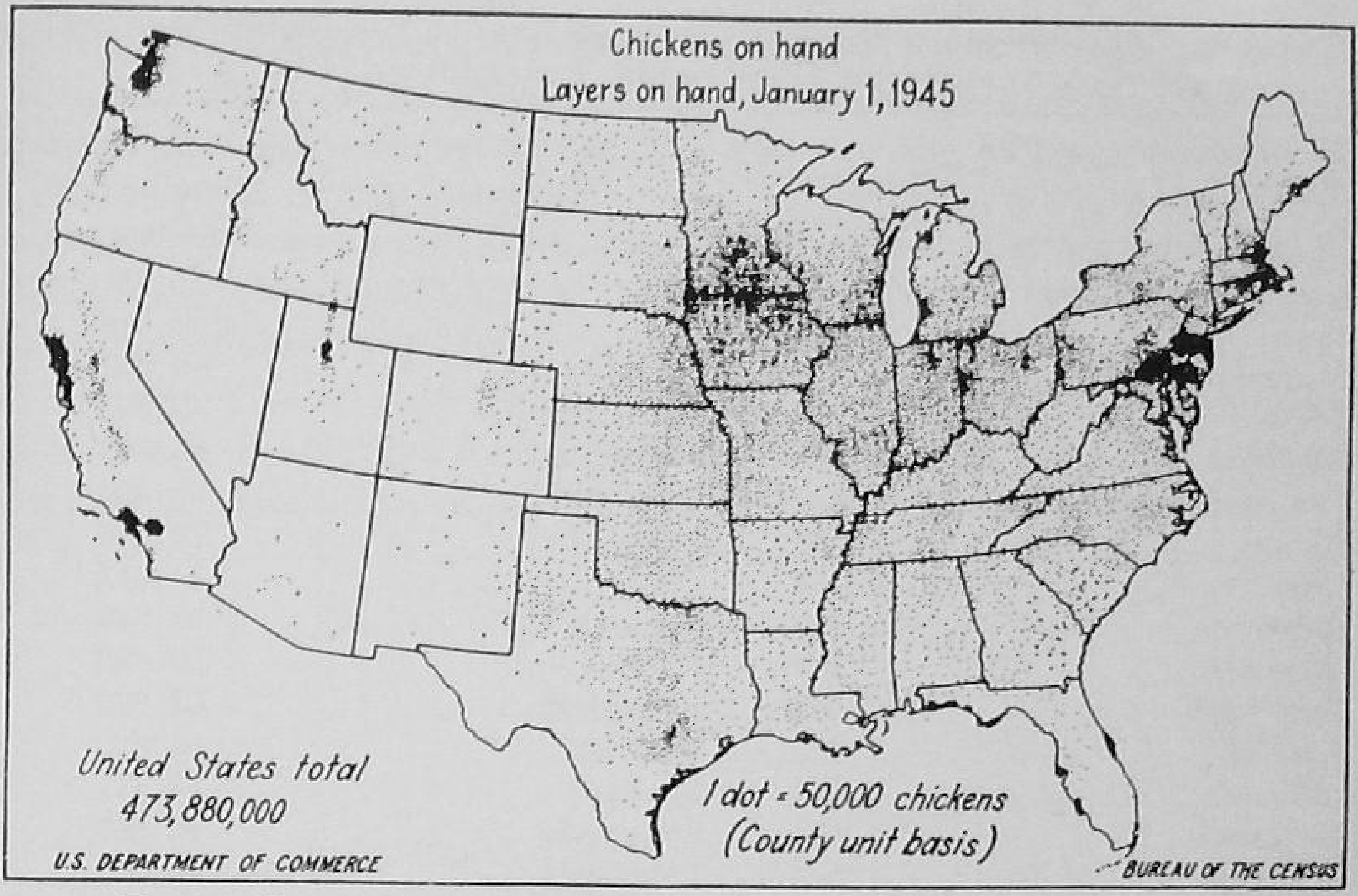

FIG. 3. Showing approximate distribution of layers on hand Jan. 1, 1945.

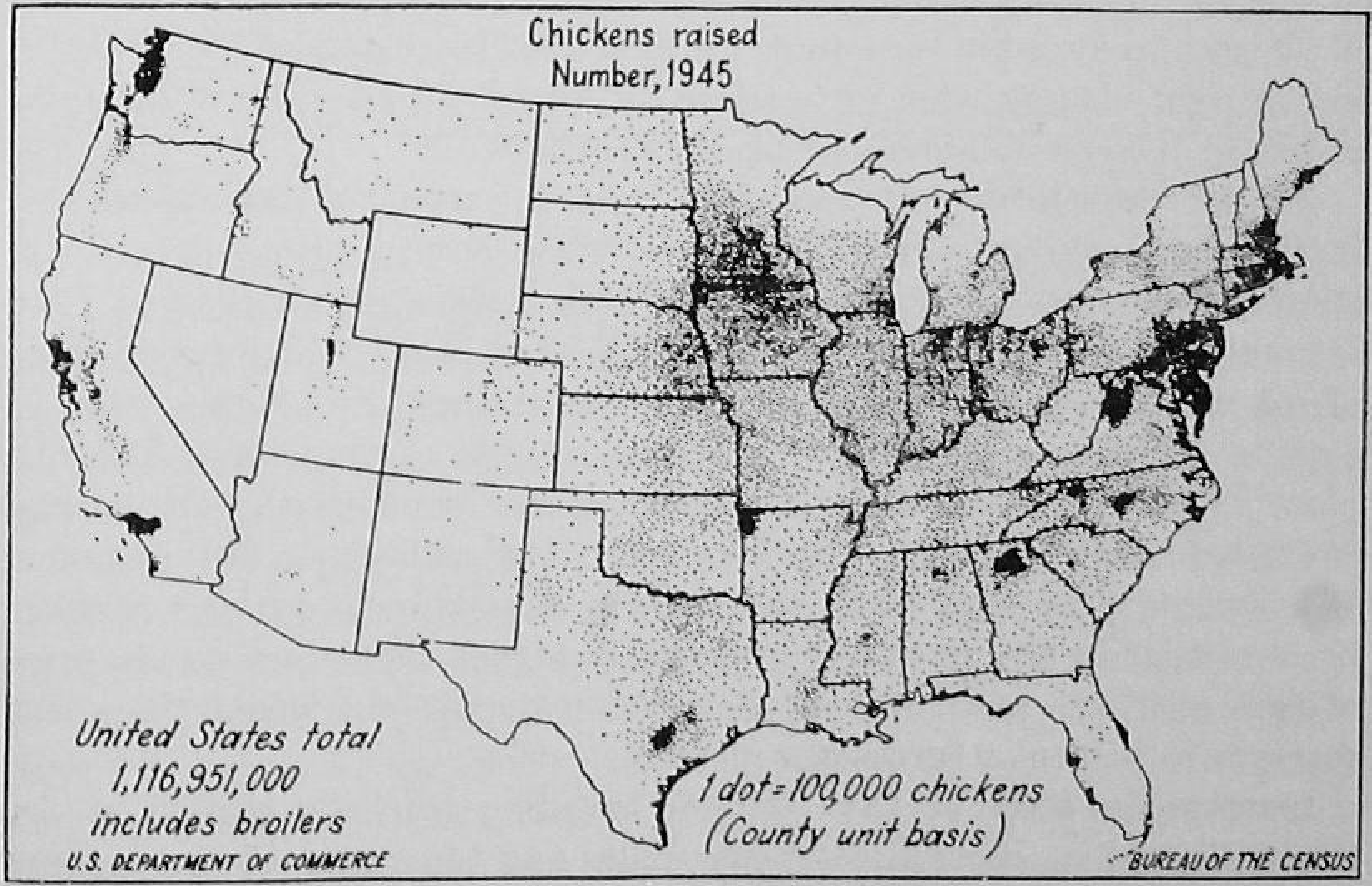

FIG. 4. Showing approximate distribution of chickens raised in 1945. Commercial-broiler raising is carried on in several areas containing the greatest concentration of dots on the map.

TABLE 2. THE 15 LEADING STATES IN AVERAGE ANNUAL EGG PRODUCTION AND IN AVERAGE ANNUAL GROSS EGG INCOME, RESPECTIVELY, 1942 TO 1946

State	Eggs produced, millions	State	Gross egg income, thousands of dollars
Iowa	4,138	Iowa	108,916
Minnesota	3,584	Minnesota	96,662
Texas	3,211	Pennsylvania	89,798
Missouri	2,825	Texas	85,529
Pennsylvania	2,675	California	76,602
Illinois	2,658	New York	76,145
Ohio	2,588	Ohio	74,712
California	2,282	Missouri	72,848
Wisconsin	2,272	Illinois	70,428
New York	2,169	Wisconsin	63,960
Kansas	2,102	Kansas	53,822
Indiana	1,974	Indiana	53,447
Nebraska	1,854	Nebraska	46,867
Michigan	1,579	Michigan	46,003
Oklahoma	1,455	New Jersey	41,720

The 15 states in the left column of Table 2 produced over 68 per cent of all eggs produced in the country during 1942 to 1946, and the 15 states in the right column were responsible for almost 70 per cent of the total gross egg income obtained during 1942 to 1946.

All the states in the left column of Table 2, except Oklahoma, are also in the right column, although some of them occupy different ranks in the two columns. In spite of the fact that Oklahoma's 1942 to 1946 average egg production exceeded that of New Jersey, the average price of eggs in New Jersey was sufficiently higher than the average price of eggs in Oklahoma to give New Jersey instead of Oklahoma fifteenth place in the right column. The same factor explains the changes of status of some states in the left and right columns. For instance, Pennsylvania occupies fifth place in the left column, but the average price of eggs in the state was sufficiently higher than the average price of eggs in Texas and Missouri that Pennsylvania outranked these two states with respect to gross egg income.

Increase in Rate of Lay. Better breeding methods carried on by poultry breeders, more bred-to-lay males and females used in hatchery flocks, an improvement in the average quality of chicks sold by hatcheries to farmers and commercial-egg producers, the feeding of more completely balanced diets, and more efficient laying-flock management have all contributed to an increased rate of lay during recent years. From

1937 to 1947 the increased rate of lay amounted to over 20 eggs, as shown in Fig. 5. Rate of lay was determined each year by dividing the total number of eggs produced during the year by the average number of layers on hand during the year.

Rate of lay was 14 per cent higher in 1947 than in 1942 and 43 per cent higher than in 1928, although the number of layers on farms at the beginning of each of the three years was practically the same.

Table 3 gives the rank of the first 15 states with respect to the number of farm-raised chickens produced during 1942 to 1946 and the rank of the first 15 states with respect to gross farm-raised chicken income.

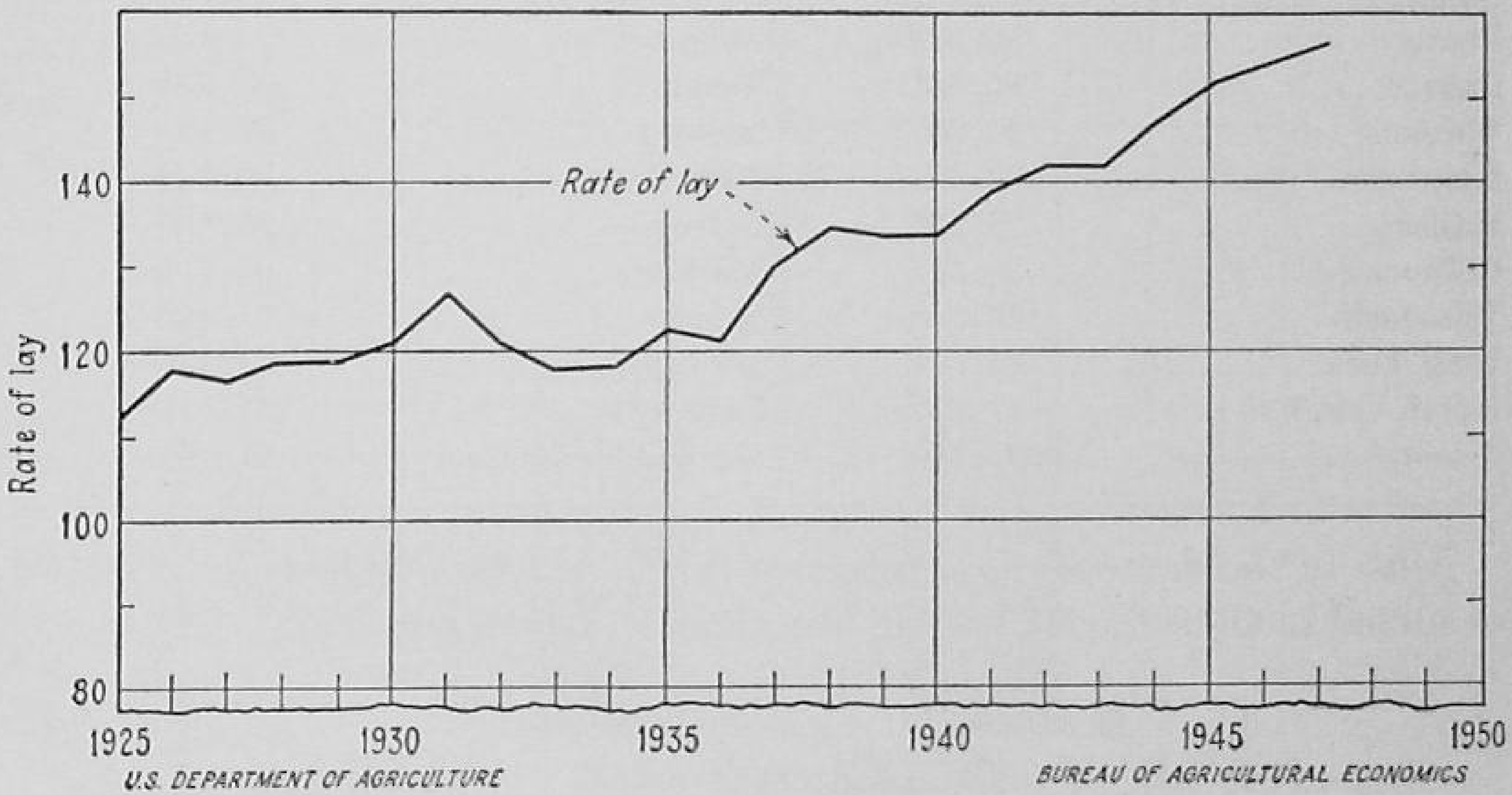

Fig. 5. Rate of lay from 1925 to 1947.

The 15 states in the left column of Table 3 were responsible for over 63 per cent of the farm-raised chickens produced in the country during 1942 to 1946, and the 15 states in the right column were responsible for over 64 per cent of the total gross farm-raised chicken income during 1942 to 1946.

The states listed in Table 3 are the same as those listed in Table 2, except that Oklahoma and New Jersey are listed in Table 2 but not in Table 3 and North Carolina is listed in Table 3 but not in Table 2.

Small Flocks Predominate. The chicken industry of the United States is largely a farm-flock enterprise. Over 50 per cent of the eggs and farm-raised chickens produced each year come from flocks of less than 200 layers per flock. Nevertheless, during recent years an important trend has been the decline in the number of farms producing eggs but an increase in egg production. Figure 6 shows that from 1934 to 1944 the number of farms on which eggs were produced declined from over 5.6 million to about 4.75 million, a decrease of 15 per cent.

TABLE 3. THE 15 LEADING STATES IN AVERAGE ANNUAL NUMBER OF FARM-RAISED CHICKENS PRODUCED AND IN GROSS FARM-RAISED CHICKEN INCOME, RESPECTIVELY, 1942 TO 1946

State	Farm-raised chickens produced, thousands	State	Gross farm-raised chicken income thousands of dollars
Iowa	55,460	Iowa	60,054
Minnesota	43,850	Pennsylvania	47,105
Texas	43,018	Illinois	40,407
Missouri	37,206	Minnesota	39,387
Illinois	37,012	Ohio	38,177
Pennsylvania	36,572	Missouri	34,168
Ohio	31,987	Texas	33,625
Indiana	30,607	Indiana	32,223
Nebraska	30,594	New York	30,343
Kansas	28,688	Nebraska	26,845
California	25,653	Michigan	26,199
Wisconsin	23,144	Kansas	24,193
New York	22,607	Wisconsin	22,748
North Carolina	22,552	California	22,118
Michigan	21,603	North Carolina	21,601

Most of the decrease in numbers of farms on which eggs were produced occurred in those farms having less than 50 layers per flock. There was

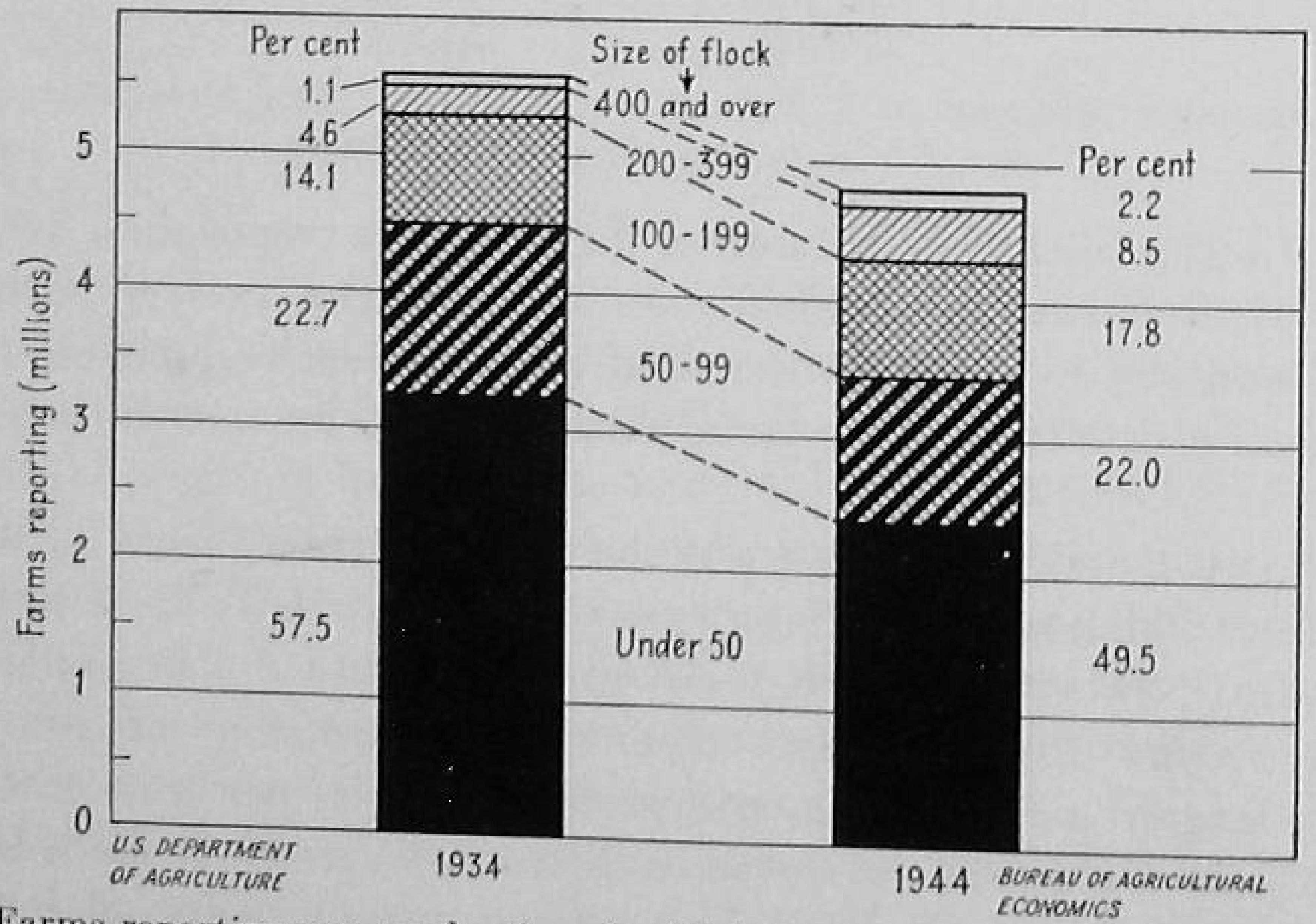

FIG. 6. Farms reporting egg production classified by size of laying flock, 1934 and 1944.

a slight decrease in the number of farms having between 50 and 99 layers per flock. On the other hand, the number of farms with flocks having between 100 and 199 layers per flock increased from 14.1 per cent of the

total number of farms in 1934 to 17.8 per cent of the total number of farms in 1944. Also, the number of farms having more than 200 layers per flock rose from 5.7 per cent in 1934 to 10.7 per cent in 1944.

Between 1934 and 1944, the most significant changes in the size of laying flocks occurred in the Northeastern, Middle Atlantic, and North Central states, the shift in average size of flock being very pronounced. Relatively little change occurred in the size of laying flocks in the Mountain and Pacific states, since, for the most part, egg production was quite highly commercialized by 1934. Moderate shifts to large laying flocks took place in the South Central states, but in the East South Central and West South Central states laying flocks of less than 100 layers per flock are the rule.

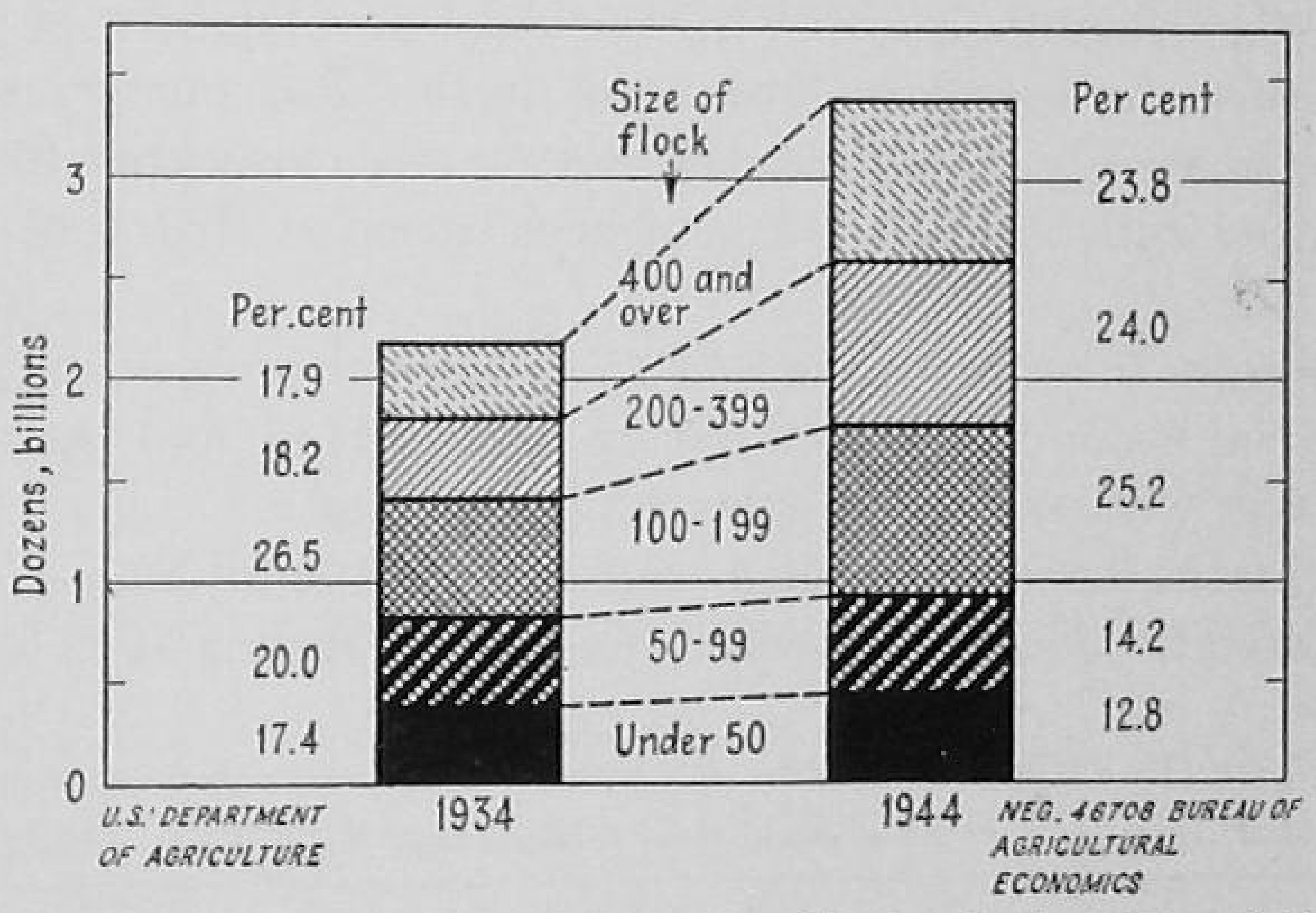

FIG. 7. Egg production classified by size of laying flock, 1934 and 1944.

In 1934, 57.5 per cent of the farms had less than 50 layers per flock, and these smallest sized flocks were responsible for 17.4 per cent of the total egg production, whereas in 1944 the number of these farms having less than 50 layers per flock had decreased to 49.5 per cent of all farms reporting egg production and these flocks produced 12.8 per cent of the total egg production (see Fig. 7). On the other hand, in 1934, farms with 200 or more layers per flock produced 36.1 per cent of the total egg production, whereas in 1944 farms with 200 or more layers per flock produced 47.8 per cent of the total egg production, as shown in Fig. 7.

Shifts toward Commercialization. During recent years there has been a definite trend toward increased commercialization of flocks, both with respect to breeding flocks and market-egg-producing flocks. This increase has occurred principally in the same areas where the principal increases in size of farm laying flocks have occurred. There are over 300,000 commercial-poultry farms in the United States at present.

BROILER PRODUCTION

The commercial-broiler industry as it is known today had its beginnings in the early 1920's, although "out-of-season" or "hothouse" chickens, as they were often called, were produced in limited numbers in the vicinity of Hammonton, N.J., as early as 1880. About 1920, winter and early spring broilers were grown in New Hampshire, and by 1928 the enterprise was quite extensively developed for those times. The world's most intensive commercial-broiler area had its beginnings in 1923 in the Delmarva Peninsula, which embraces the adjoining counties of Delaware, Maryland, and Virginia. By 1927 broilers were produced extensively in Benton County, Ark.

The primary factors involved in the initial development of the broiler industry were the extreme shortage of fresh-killed poultry during the late winter and early spring months and the discovery that feeding diets supplemented with vitamin D to chickens raised at that time prevented rickets.

Table 4 gives the rank of the first 15 states with respect to the number of commercial broilers produced during 1942 to 1946, and the rank of the first 15 states with respect to gross broiler income.

The 15 states listed in Table 4 were responsible for 82 per cent of all the commercial broilers produced in the country during 1942 to 1946, and

TABLE 4. THE 15 LEADING STATES IN AVERAGE ANNUAL NUMBER OF BROILERS PRODUCED AND IN GROSS BROILER INCOME, RESPECTIVELY, 1942 TO 1946

State	Broilers produced, thousands	State	Gross broiler income, thousands of dollars
Delaware	58,735	Delaware	$49,800
Maryland	32,604	Maryland	28,828
Virginia	21,720	Virginia	19,624
Georgia	20,591	Georgia	17,024
Arkansas	15,190	Arkansas	12,080
North Carolina	13,630	North Carolina	11,285
Texas	13,127	California	10,513
California	10,790	Texas	7,922
Connecticut	7,716	Connecticut	7,348
Illinois	7,347	West Virginia	6,821
West Virginia	7,098	Illinois	6,497
Indiana	5,895	New York	5,464
New York	5,878	Indiana	5,427
Florida	5,422	Pennsylvania	5,089
Pennsylvania	5,135	Florida	4,865

for almost 87 per cent of the total gross commerical-broiler income during 1942 to 1946.

A factor of major importance in the commercialization of the Delmarva broiler industry was the relative proximity of that area to the New York City and other eastern markets, overnight truckloads of live broilers being delivered to these markets in the early morning hours. Subsequently, poultry-dressing plants were established which made it possible to deliver dressed broilers to these eastern markets still possessing the "fresh-killed" flavor. That in itself proved to be a tremendous asset.

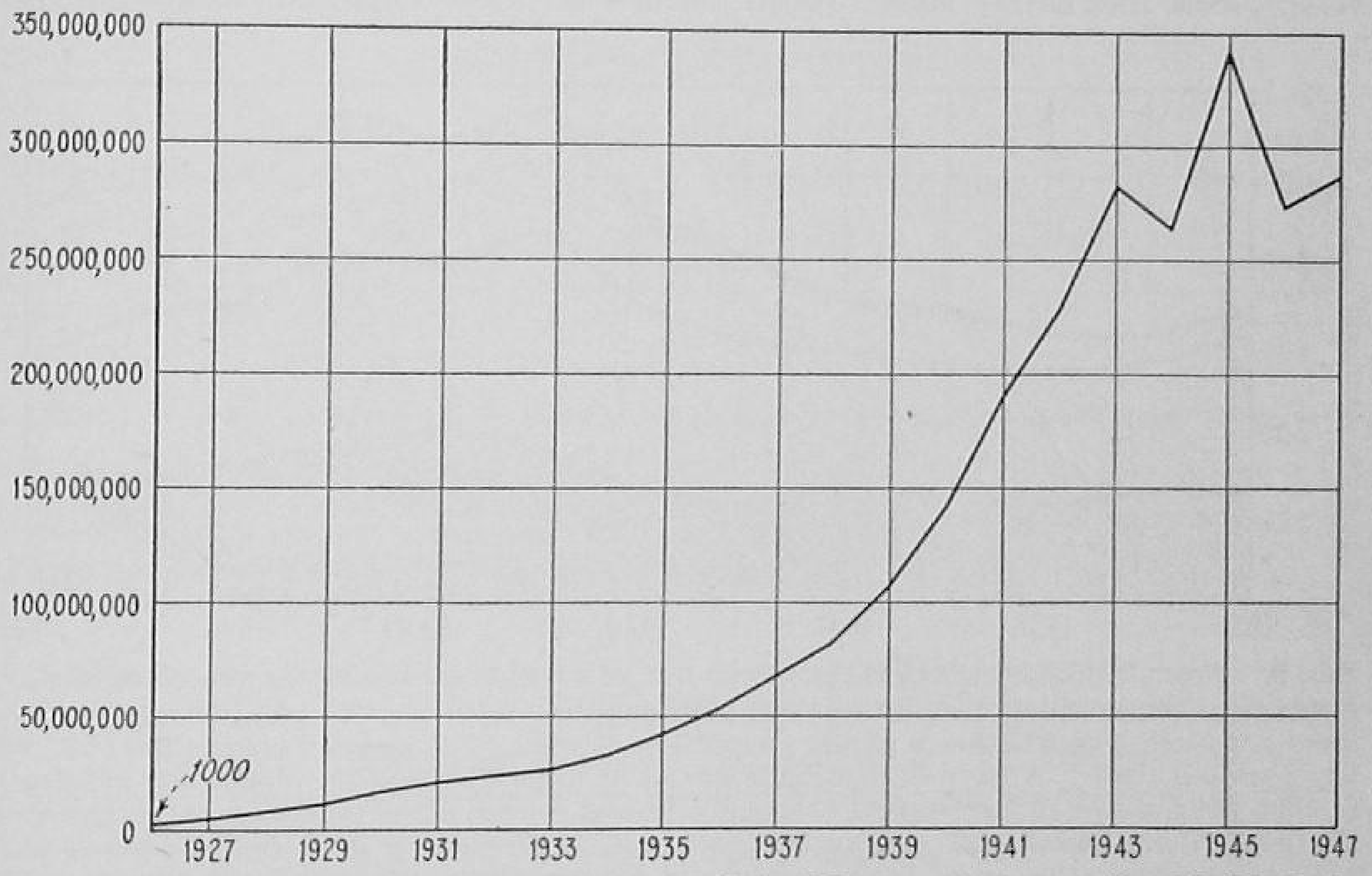

FIG. 8. Broilers produced commercially in the United States, 1926 to 1947. (*J. M. Gwin*, 1948.)

The principal reasons why commercial-broiler production developed so extensively in such areas as the Delmarva Peninsula, Arkansas, and somewhat later in Georgia, Virginia, and other states include the following: (1) relatively mild winters, (2) relatively low house-construction costs, (3) relatively cheap labor, (4) sandy or other suitable types of soil, and (5) the providing of employment for farmers who were normally engaged in truck-crop production or other agricultural enterprises which required but little labor during the winter months.

Factors Affecting Expansion of Industry. There are several factors to account for the remarkable expansion of the broiler industry during the past few years. Many of these factors will affect the future development of the industry.

One of the most obvious factors that has affected the expansion of the

broiler industry has been the increase in the human population. This factor will continue to exercise its influence in future developments. Coupled with this factor of increased population is the factor of increased consumer demand for cut-up chicken ready to fry.

Another factor, not so obvious but nevertheless very important, has been the marked increase over the years in average egg production per hen. Relatively fewer chicks have been purchased by farmers each year for laying-flock replacement purposes than would have been purchased if rate of lay had not increased, and thus relatively fewer surplus cockerels have been marketed than would otherwise have been the case. Also,

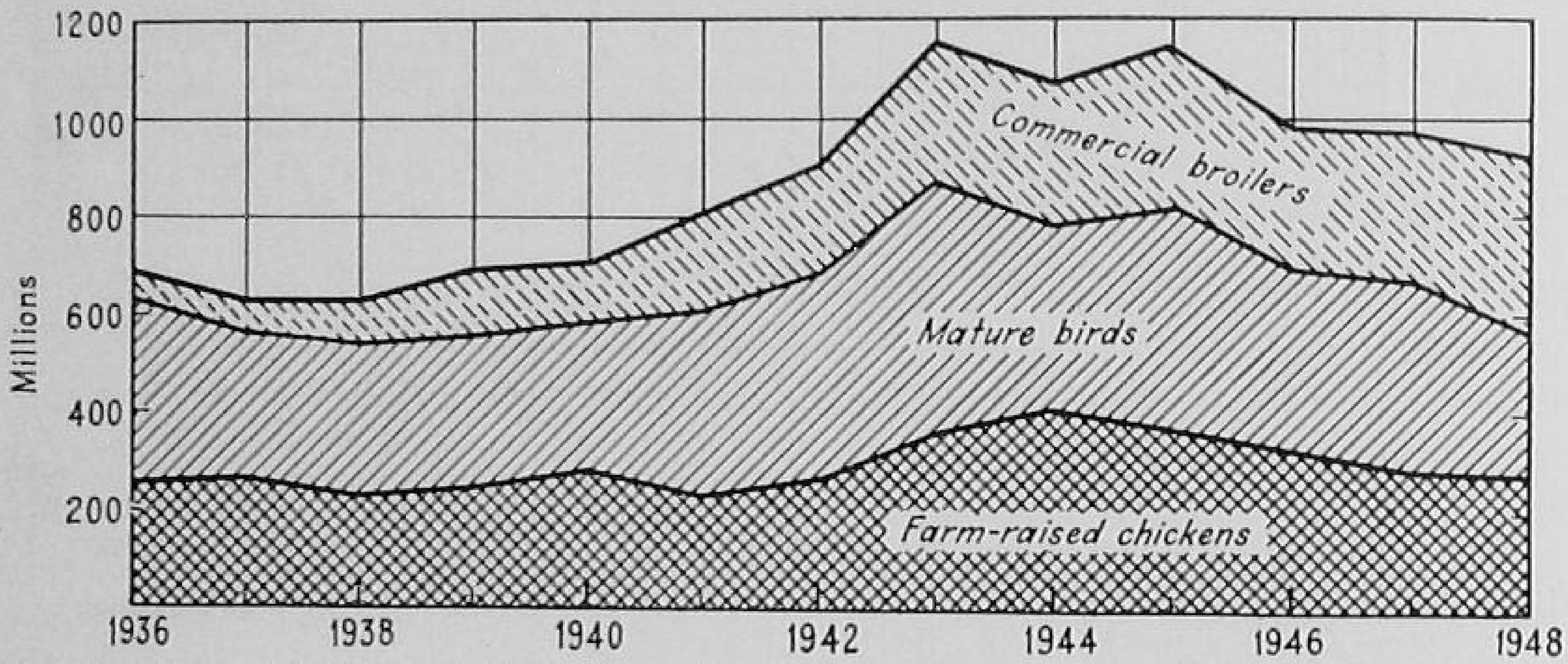

FIG. 9. From 1936 through 1948 the production of commercial broilers increased relatively faster than the production of farm-raised chickens and mature birds. At present, broiler-meat production constitutes a higher proportion of total chicken-meat production than at any previous time. A word of caution is advisable in interpreting the chart: For instance, in 1936 the number of farm-raised chickens sold and consumed on producers' premises was 252 million; the number of mature birds sold and consumed on producers' premises was 378 million; the number of broilers sold and consumed on producers' premises was 53 million.

relatively fewer culled hens have been marketed each year as compared with the larger numbers that would have had to have been sold if average egg production per bird had not increased to the extent that it has.

The fact that broiler production provides relatively quick returns on the money invested in the enterprise as compared with many other branches of farming is another reason why so many people have become interested in raising broilers.

A factor that has resulted in greater efficiency of operation during recent years, and thus has tended to expand the industry, has been the construction of wider buildings equipped with central-heating systems, automatically controlled mechanical feeders, and automatically controlled waterers, all of which have meant that many more broilers can be cared for per man than formerly. In addition, these wider houses make pos-

sible the use of a manure spreader or truck in cleaning out the house, thus reducing labor requirements for this particular job.

Still another factor that has affected the increased consumer demand for fresh-killed, cut-up chicken ready to fry, and thus has influenced further growth of the broiler industry, has been the relatively high level of consumer purchasing power that has prevailed during recent years.

The future development of the commercial-broiler industry will be affected by all these factors and in addition by the future per capita consumption of broilers, which will be influenced by improvement in the quality of broilers sold, competition from red meats, and family incomes.

THE HATCHERY INDUSTRY

The commercial development of the hatchery industry had its beginnings in the 1880's, although it was not until the manufacture of mammoth incubators in the 1890's that the hatchery expanded to an appre-

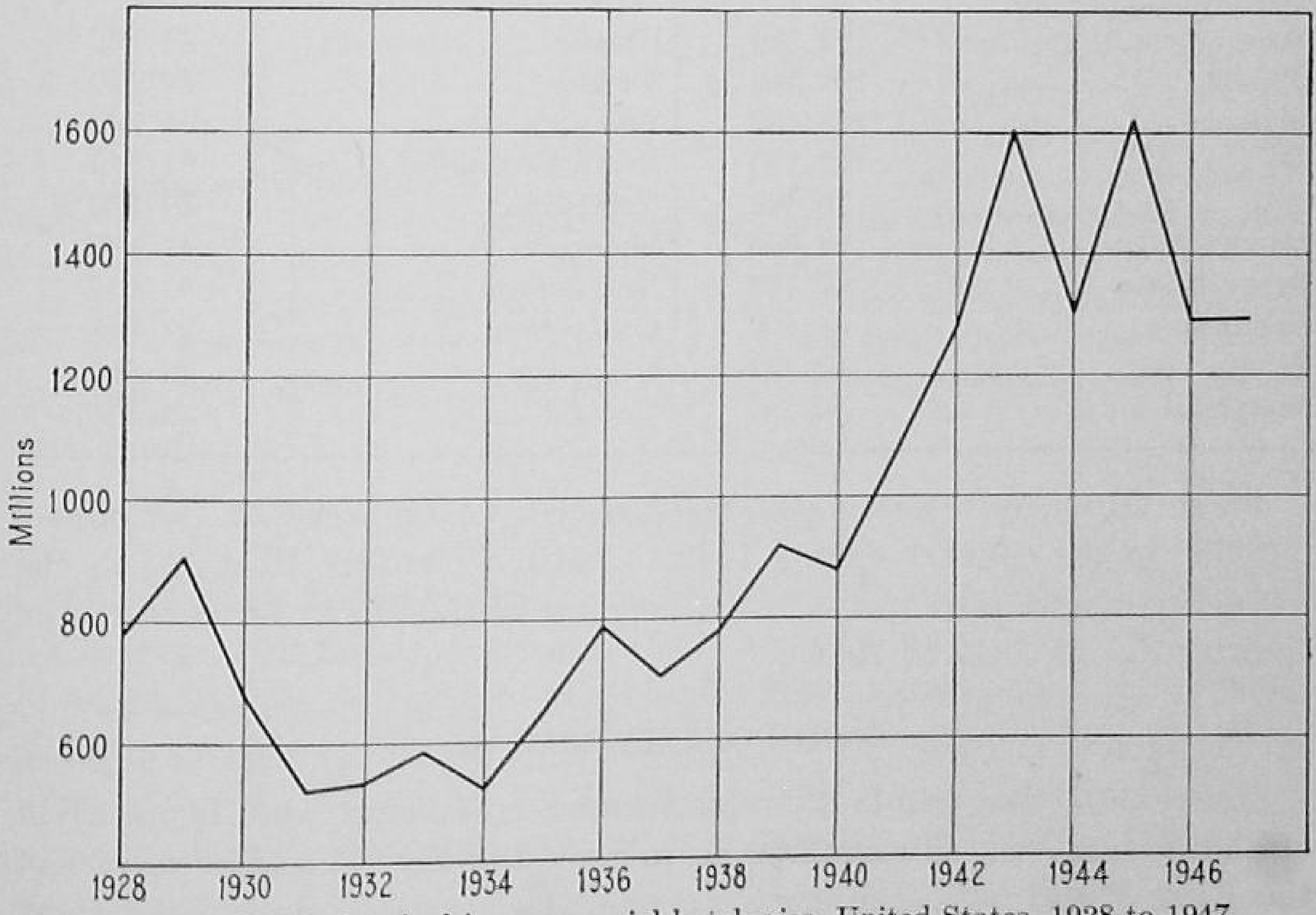

Fig. 10. Chicks hatched in commercial hatcheries, United States, 1928 to 1947.

ciable extent. A significant stimulant to the industry occurred when chicks were admitted to the mails on May 15, 1918.

In 1928 about 22 per cent of all chicks hatched in the United States were hatched in commercial hatcheries, whereas by 1947 the figure had risen to about 90 per cent.

In 1938, there were 10,531 hatcheries with a capacity of 397,376,000 eggs. In 1943, there were 10,112 hatcheries with a capacity of 504,640,-

000 eggs. In 1948, there were 9,341 hatcheries with a capacity of 551,847,000 eggs.

Figure 10 shows the effects of the period of economic depression, 1930 to 1935, on the decreased demand for chicks. Beginning about 1936 the continued expansion of the broiler industry led to increased hatchery output, which was greatly accelerated during the Second World War. Also, during the war period, there was greatly increased demand for chicks for laying-flock replacement purposes and for "broiler" chicks.

Table 5 gives the rank of the first 20 states with respect to numbers of chicks hatched during 1942 to 1946.

TABLE 5. THE 20 LEADING STATES IN AVERAGE ANNUAL NUMBERS OF CHICKS HATCHED, 1942 TO 1946

State	Chicks hatched, thousands	State	Chicks hatched, thousands
Missouri	112,695	Kansas	43,792
Illinois	106,266	Virginia	36,785
Indiana	103,687	Delaware	35,927
Iowa	102,190	North Carolina	34,519
Ohio	76,496	Nebraska	34,183
Minnesota	68,066	Michigan	32,138
Pennsylvania	67,776	New Jersey	31,044
California	64,400	Connecticut	29,866
Texas	60,429	Oklahoma	29,694
Maryland	52,216	Georgia	29,305

These 20 states were responsible for over 81 per cent of the chicks hatched in the country during 1942 to 1946. The first 10 states in the left column were responsible for 71 per cent of the chicks hatched in the country during 1942 to 1946.

CASH POULTRY INCOME

Since 1910 the trends in cash income from eggs and farm-raised chickens show wide fluctuations, as indicated in Fig. 11. The impact of the First World War, the serious economic depression during the early thirties, and the Second World War affected both volume of production and prices, which in turn affected cash farm income. Broiler production, being a relatively recent development, has not experienced the same fluctuations in cash income as the other branches of the chicken industry.

Two factors of major importance in the marked increase in cash farm income from eggs, farm-raised chickens, and broilers from 1942 to 1947 have been higher prices and increased per capita consumption of eggs and chicken meat.

During 1945 to 1947, the value of eggs consumed on the producers' premises amounted to slightly over 14 per cent of the total gross egg income. The value of the farm-raised chickens consumed on the pro-

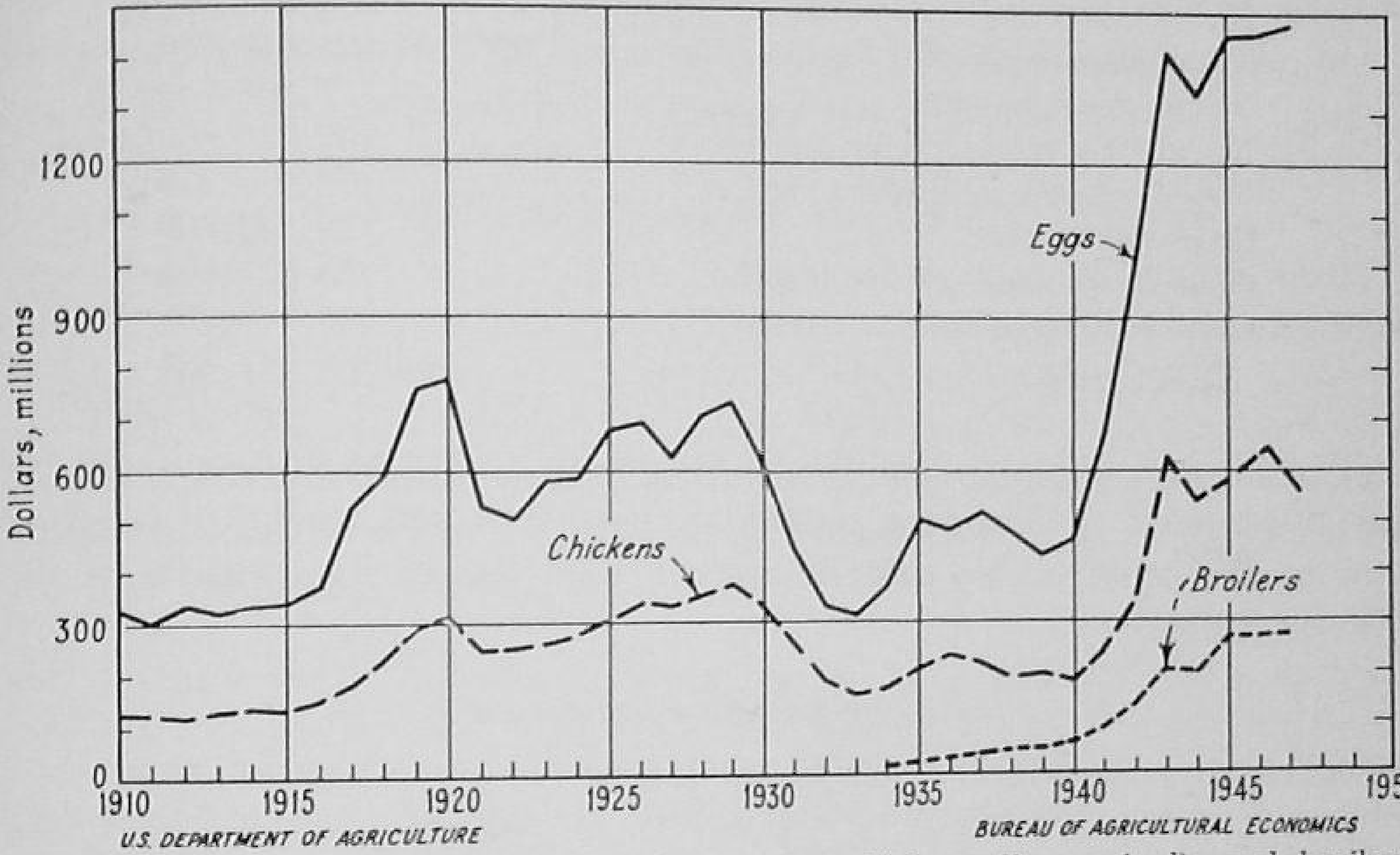

FIG. 11. Cash farm income obtained from eggs, chickens (farm-raised), and broilers, United States, 1910 to 1947.

ducers' premises was over 22 per cent of the gross farm-raised chicken income and over 16 per cent of the gross income from farm-raised chickens and broilers.

A VALUABLE ASSET

The chicken industry is a valuable asset, since it not only provides consumers with highly nutritious food products but adds several million dollars annually to the income obtained from agriculture. Also, many millions of tons of feed are converted into food products on a relatively efficient basis. On many farms, family labor in caring for the flock is utilized more advantageously than is possible with numerous other enterprises.

The production of eggs and chicken meat provides employment not only for those engaged in the production of these products but also for hatchery operators, feed dealers, manufacturers of incubators, equipment, building materials, egg cases, poultry coops, cars, and trucks, processors of egg and poultry products, and all dealers engaged in the marketing of eggs and poultry from the time they leave the producers' premises until they are in the hands of the consumers.

Some conception of the magnitude of the chicken industry may be

gained by a glance at the following average annual figures for 1942 to 1946, inclusive:

No. of layers on hand on Jan. 1	477,714,000
No. of layers on hand during the year	369,875,000
No. of eggs produced	54,627,000,000
No. of chicks hatched	1,412,843,000
No. of farm-raised chickens produced	760,024,800
No. of commercial broilers produced	273,148,800
Gross egg income	$1,578,569,800
Gross farm-raised chicken income	775,677,000
Gross commercial-broiler income	239,710,400
Total gross income	$2,593,957,200

The chicken industry has demonstrated its ability to adjust itself, for the most part, to changing economic conditions and maintain itself as one of the most stable and important branches of agriculture in the United States.

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CHAPTER 2

THE BREEDS OF CHICKEN

The original habitat of the ancestor of modern breeds of chickens is south and central India, the Himalayan Terai, Assam, Burma, Ceylon, and throughout all the countries to the southward, on into Sumatra and Java with its string of lesser islands to the eastward. There are four known species of wild fowl, and they belong to the same genus called "Gallus," meaning a cock.

FIG. 12. The *Gallus bankiva* species of wild fowl, the male of which is shown here, is regarded by many authorities as being the principal one of the four wild species from which modern breeds have descended. (*U.S. Dept. Agr.*)

The four species are as follows: (1) *Gallus gallus* or *Gallus bankiva*, the Red Junglefowl; (2) *Gallus lafayetti*, the Ceylon Junglefowl; (3) *Gallus sonneratii*, the Grey Junglefowl; (4) *Gallus varius*, the Javan Junglefowl. The Javan Junglefowl differs from the other three species in having a single-median wattle, a smooth-edged comb, truncated neck hackles, and an extra pair of rectrices, or tail feathers.

The general distribution of the four species is as follows: The Red

Junglefowl is widely distributed through eastern India, Burma, Siam, and Sumatra; the Ceylon Junglefowl in Ceylon; the Grey Junglefowl in western and southern India; the Javan Junglefowl in Java and adjacent islands.

All four species will cross with one another, and the hybrids are more or less fertile among themselves. Also, from evidence supplied by naturalists and investigators who have made crosses between each of the four wild species and domestic stocks, it appears that all hybrid progeny are fertile, with the possible exception of the female offspring of the cross between the *Gallus varius* male and domestic females. Apparently, most of the modern-day breeds are descended from these four wild species.

The sport of cockfighting exercised a tremendous influence not only in the domestication of wild birds but also in the subsequent distribution of the fowl throughout the world.

In 1873 there took place the first organized effort in the United States to place the poultry-breeding industry upon a stable basis. In that year the American Poultry Association was organized, which had for its object the formulation and adoption of a standard of excellence to be used exclusively by poultry associations in awarding prizes on exhibition poultry. A complete standard was adopted for all the then recognized varieties of domestic and ornamental classes of poultry, and in 1874 the first "Standard of Perfection" was printed. Since that time, the "Standard," revised periodically, has served as the basis of guidance in breeding operations in developing many breeds and varieties. In many respects, therefore, the standardbred poultry industry served as a foundation for the subsequent development of the industry.

Breeds and Varieties. The breeds and varieties of chickens are so numerous that a detailed discussion of all the characters they possess is not possible in this book. Moreover, the reader is referred to the "American Standard of Perfection," published by the American Poultry Association, and to the other works listed at the end of this chapter.

The breeds are classified largely from the standpoint of their origin, emphasis being placed upon the more important characteristics of economic importance in the more popular breeds and upon the unusual characteristics of those breeds and varieties bred largely for pleasure.

Breed Type. The distinguishing feature whereby one breed of fowls differs from another breed is in respect to type, although this is rather a confusing situation, inasmuch as the visible body type is influenced not only by the actual shape of the body but also by the feather contour. In breeding standardbred poultry, the "type" of bird, as determined by feather contour, has been regarded as of greatest importance, so much so that in many cases the actual body type has received minor attention.

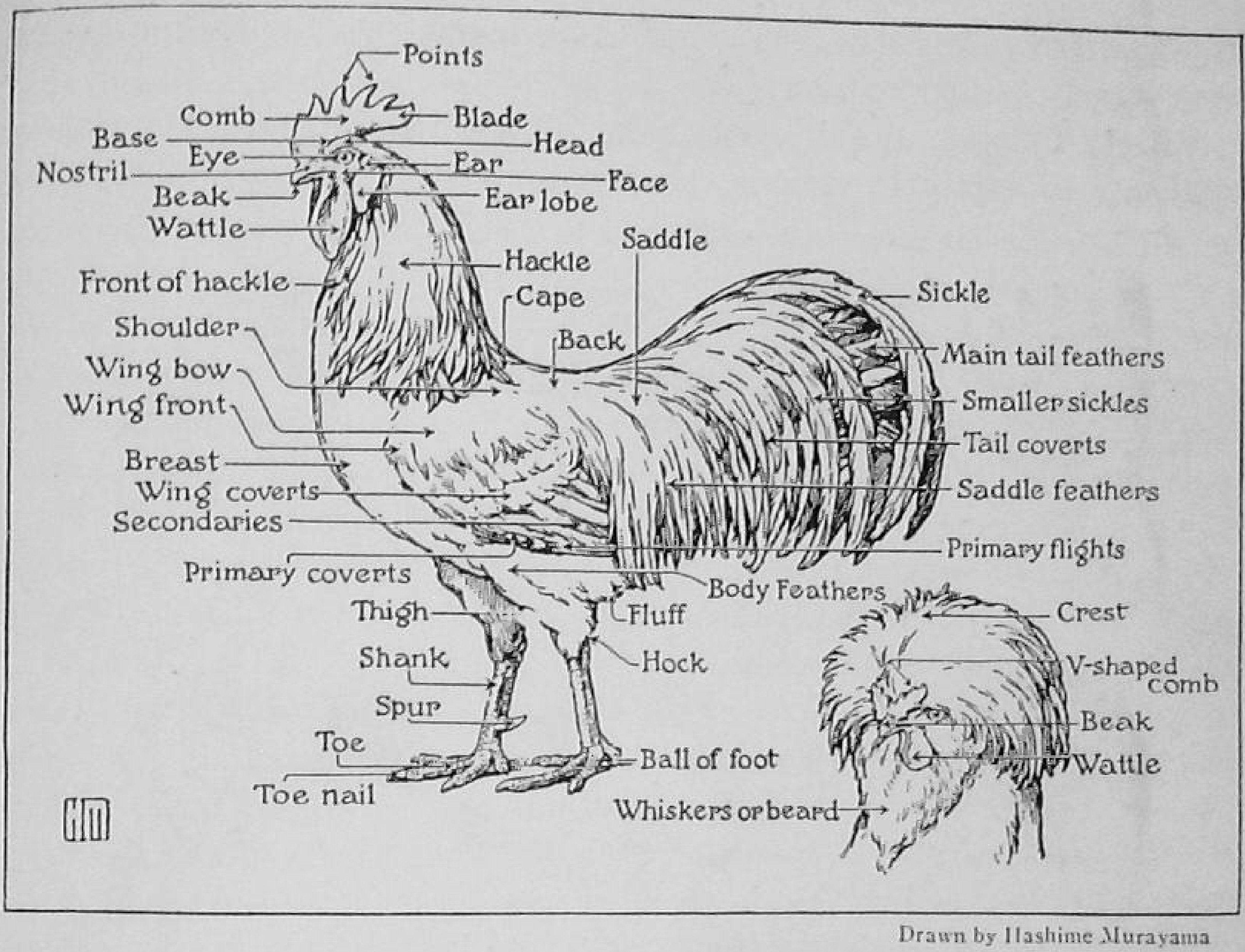


Fig. 13. An outline chart of a male. (*M. A. Jull, National Geographic Magazine*, 1927.)

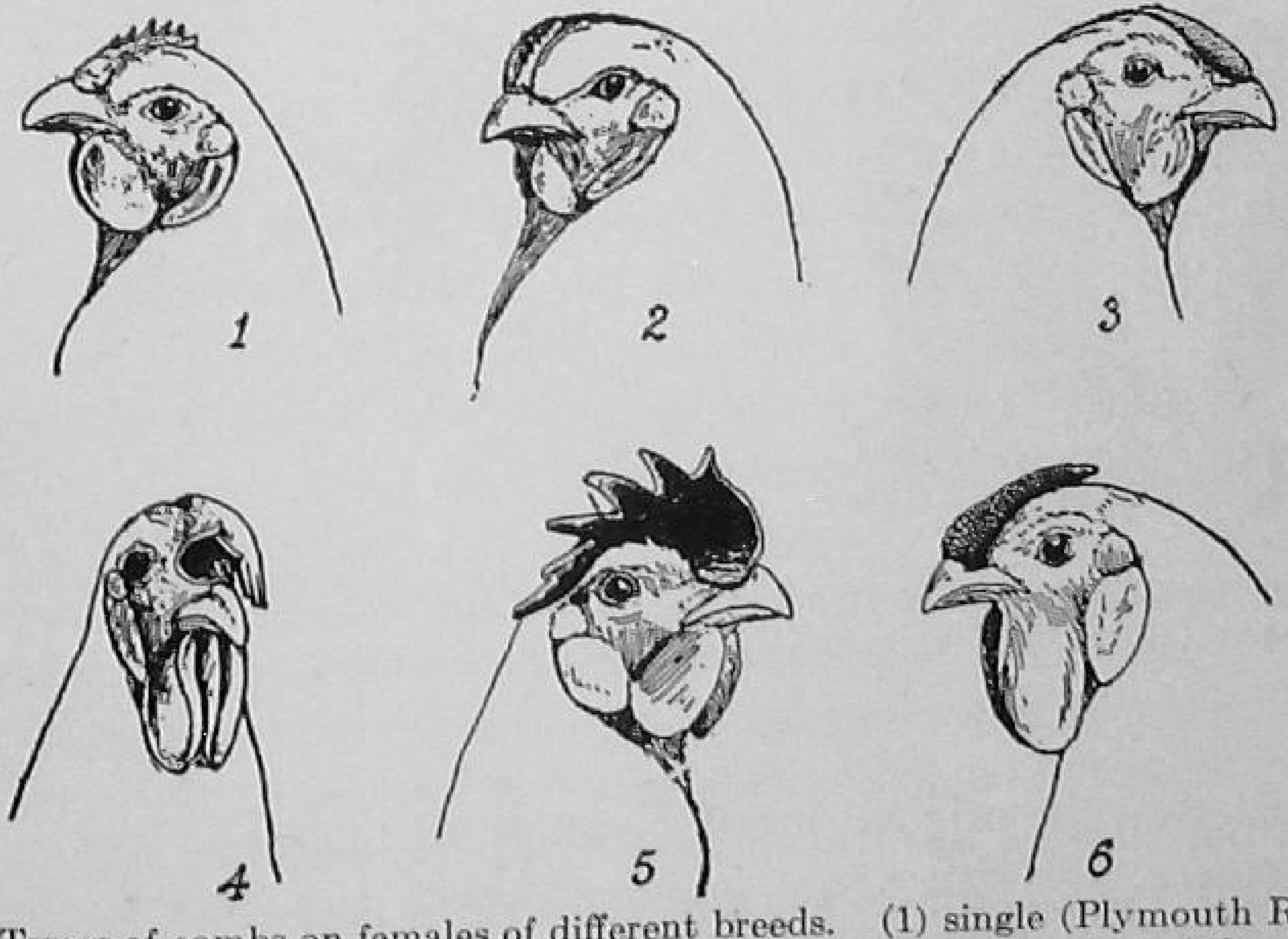


Fig. 14. Types of combs on females of different breeds. (1) single (Plymouth Rocks and Rhode Island Reds); (2) pea (Brahmas); (3) rose (Wyandottes); (4) single (Minorcas); (5) single (Leghorns); (6) rose (Rhode Island Reds). (*U.S. Dept. Agr.*)

It is now recognized that "shape makes the breed," shape here indicating very largely feather contour.

Variety Colors. Within each breed of fowls there naturally was a tendency to segregate various color combinations, or, where only one

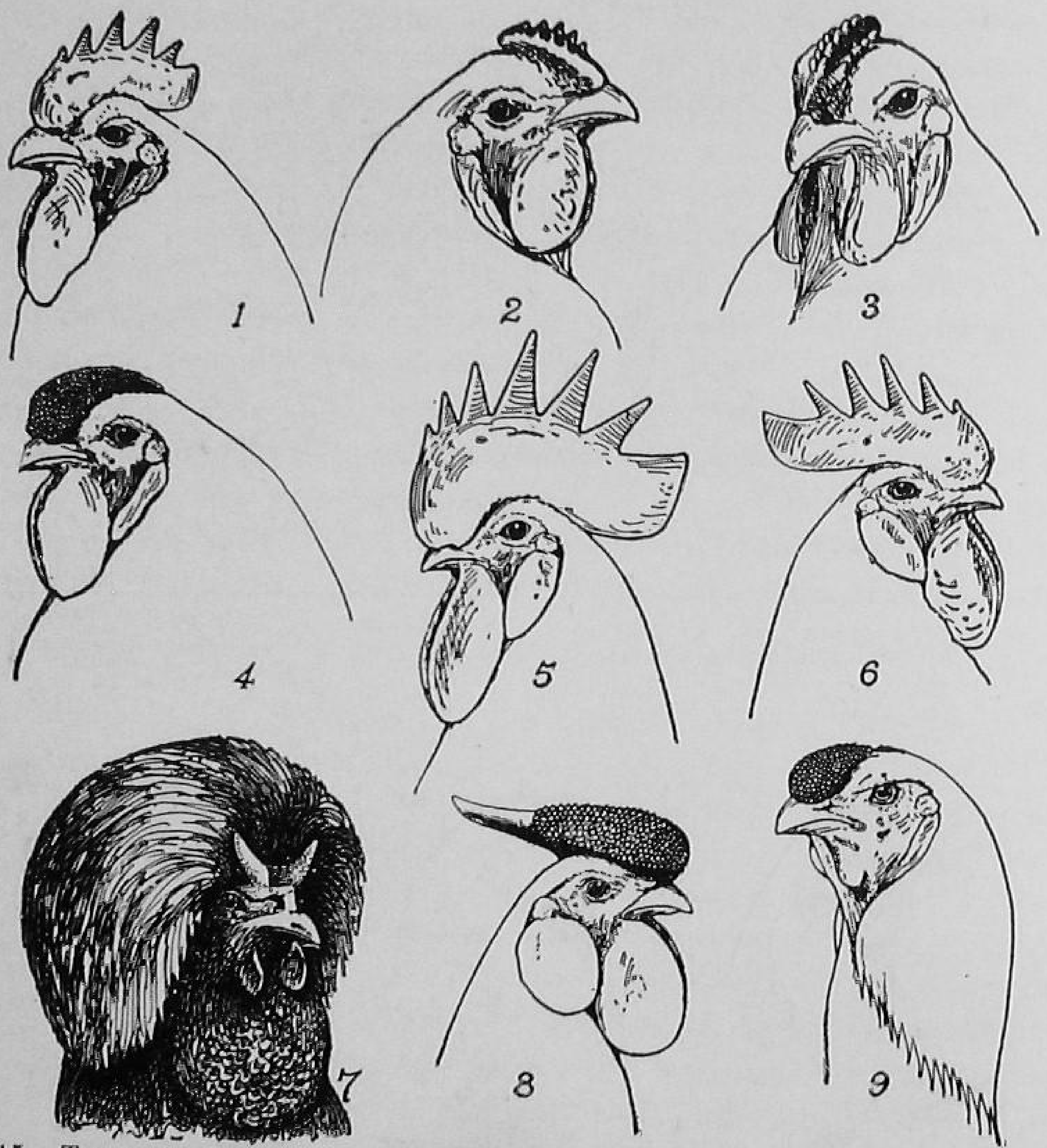


Fig. 15. Types of combs on males of different breeds. (1) single (Plymouth Rocks); (2) and (3) pea (Brahmas); (4) rose (Wyandottes); (5) single (Minorcas); (6) single (Leghorns); (7) V-shaped (Houdans); (8) rose (Hamburgs); (9) strawberry (Malays). (*U.S. Dept. Agr.*)

color existed in the original breed, there was a tendency to develop new color patterns. In either case, it was necessary to adhere to the original type or shape characteristic of the breed, and thus it has arisen that varieties of a breed are supposed to be identical in all characteristics except plumage color or, in some cases, in respect to the type of comb, standard weight, color of shanks, and other minor characteristics. There

is a large grain of truth in the old saying of poultry breeders that "shape makes the breed and color the variety."

The illustrations in the accompanying pages are designed to present the standard type of various breeds and should be studied closely. The problem of an adequate color description for the numerous varieties is simplified materially, because there are relatively few standard color patterns. For instance, the color patterns of the Dark Brahma, Silver Penciled Plymouth Rock, and Silver Penciled Wyandotte are almost identical, as is also the case with the color patterns of the Light Brahma, Columbian Plymouth Rock, and Columbian Wyandotte. The plumage pattern and feather markings of the Partridge Cochin are identical with those of the Partridge Plymouth Rock and Partridge Wyandotte. In certain breeds there are silver-laced and golden-laced varieties, in the latter the white of the silver-laced variety being replaced by red and reddish brown. There are black varieties and white ones of many breeds, and there are blue varieties of a few breeds, in each case the color being identical.

The standard weights of representative breeds are given in Table 6, and the type of comb and color of ear lobe, skin, shanks, and egg of these same breeds are given in Table 7. Comb types are shown in Figs. 14 and 15.

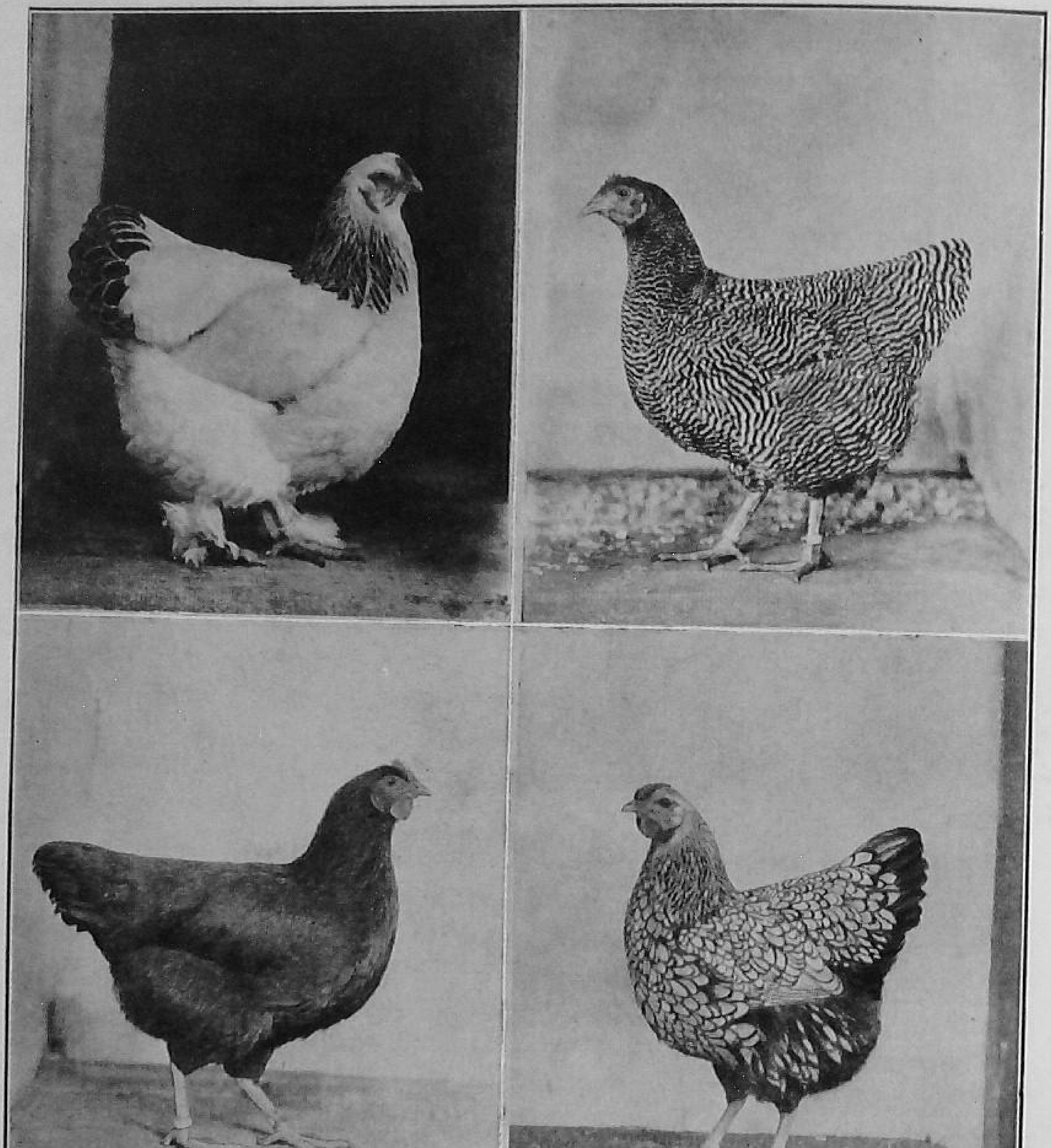
AMERICAN BREEDS

A number of breeds have been developed in America to meet the market demand for a bird with a yellow skin, unfeathered shanks, and adapted to the conditions of the country. With one or two exceptions all American breeds have yellow shanks; except for the Lamona, all have red ear lobes; all lay brown-shelled eggs.

Chickens of relatively small size with black-and-white bars and usually with rose combs were common in many parts of the eastern United States as early as 1750. They were recognized under the breed name of Dominique, but their popularity soon waned.

Plymouth Rock. The Plymouth Rock is rather long bodied, fairly broad, and with fairly prominent breast and good depth of body. The varieties of Plymouth Rock include the Barred, White, Buff, Blue, Columbian, Partridge, and Silver Penciled.

In the development of the *Barred Plymouth Rock*, Dominique breeding stock was used to some extent but the black-and-white barring is much more distinct in the former than in the latter. In the Barred Plymouth Rock male the black-and-white bars should be of equal width, whereas in the Barred Plymouth Rock females the white bars should be one-half as wide as the black bars.



Top, Light Brahma
Bottom, S. C. Rhode Island Red

Top, Barred Plymouth Rock
Bottom, Silver Laced Wyandotte

Fig. 16.

In the *White Plymouth Rock*, the plumage color is pure white throughout and should be free from black ticking, brassiness, and creaminess, as should be the case with all white varieties of other breeds.

The plumage color of the *Buff Plymouth Rock*, as in buff varieties of other breeds, is golden buff in all parts of the surface color, and all sections should be of the same shade. The undercolor is of lighter shade than the surface color.

The *Columbian Plymouth Rock* was developed from crosses between Light Brahmas and White Plymouth Rocks. Most of the plumage is white, although the hackle feathers of the male and the neck feathers of the female and the tail coverts of both sexes are black, with a distinct white lacing. The tail feathers in both sexes are black. The wings also carry some black on the primary and secondary feathers, which is almost hidden when the wings are folded. The undercolor of all sections in both sexes should be light bluish slate.

The *Silver Penciled Plymouth Rock* owes its feather markings, to a considerable extent, to the Dark Brahma. It has a distinctive color pattern in which the male differs considerably from the female.

The plumage of the male consists of a silvery-white surface color, extending over the wing bows and back, and the hackle and saddle are silvery white, striped with black. The rest of the plumage, including the main tail feathers and sickles, is black. The primaries are black, except for a narrow edging of white on the lower edges of the lower webs, and the secondaries are also black, with some white.

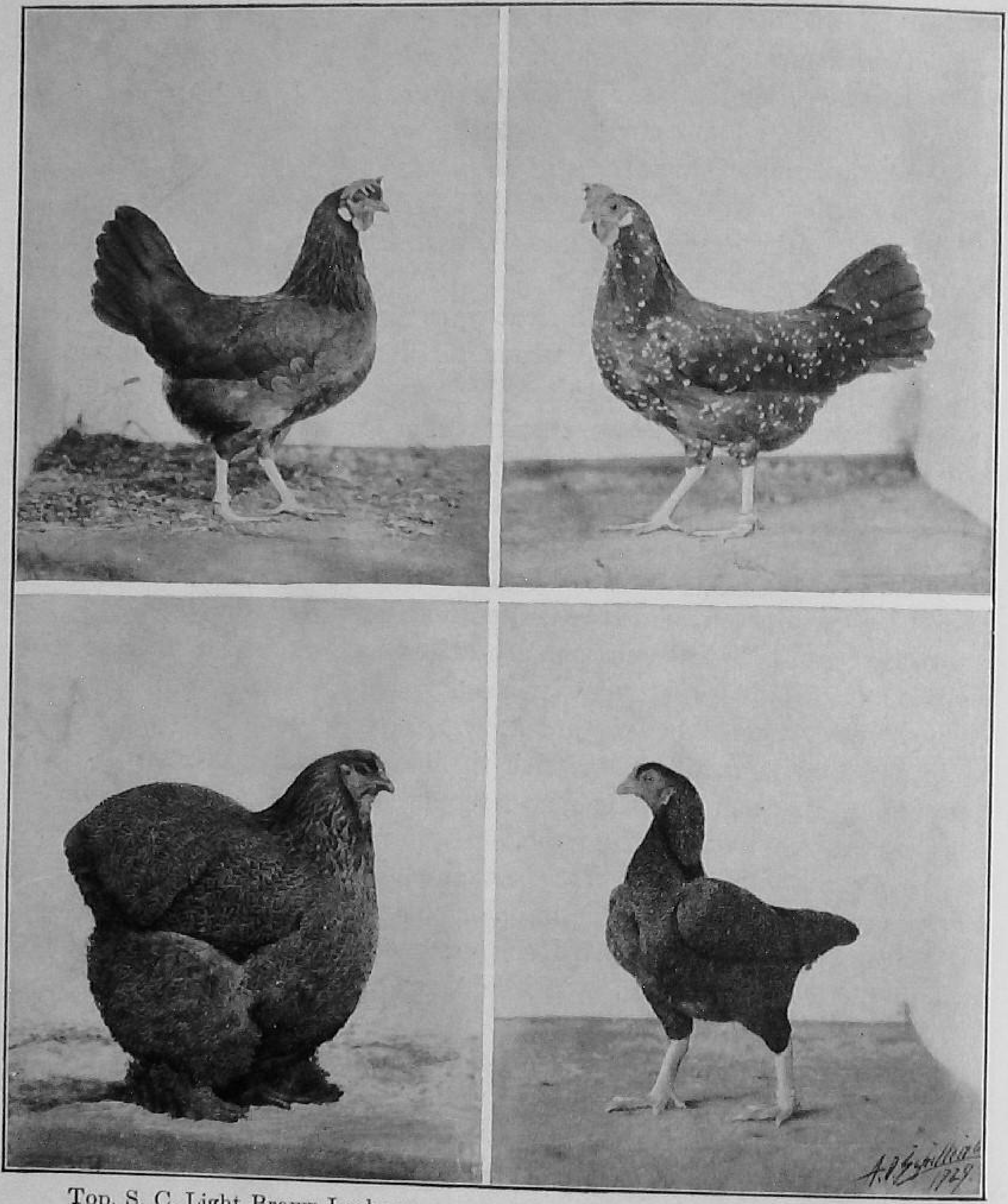
In the female the general surface color is gray, with a distinct, concentric penciling of dark gray on each feather. The neck feathers are silvery white, with a black center showing a slight gray penciling, and the main tail feathers are black, with the two top feathers showing some penciling. In both sexes the undercolor is slate, shading to a lighter color toward the base in the male.

The *Partridge Plymouth Rock*, developed apparently from Partridge Cochins and Brown Leghorns, in color pattern is practically the same as the Silver Penciled Plymouth Rock, except that the white in the Silver Penciled is replaced by red or reddish brown.

The hackle of the male is greenish black with a narrow edging of brilliant red; the plumage in front of the neck is black. The wing bow is brilliant red. The primaries are black, with the lower edges reddish bay, and the secondaries are also black, the outside web of reddish bay with greenish black at the end of each feather. The back has brilliant-red feathers, each with a greenish-black stripe down the middle.

In the female the neck is reddish bay, and the front of the neck and breast are both deep reddish bay, distinctly penciled with black. The wing bows are also deep bay penciled with black. The primaries are black with an edging of deep reddish bay on the outer webs, the inner webs of the secondaries are black, and the outer webs are reddish bay deeply penciled with black. The back is also deep reddish bay penciled with black. The undercolor of all sections of both sexes should be slate. The beak is dark horn shading to yellow at the tip.

The *Blue Plymouth Rock* has plumage of an even shade of blue, each



Top, S. C. Light Brown Leghorn
Bottom, Partridge Cochin

Top, S. C. Ancona
Bottom, Dark Cornish

Fig. 17.

feather being laced with darker blue, and in the male the lacing of the wing bows, hackle, back, saddle, sickle feathers, and tail coverts is very dark. This general description fits other blue breeds and varieties. (See the discussion on the inheritance of blue plumage under Blue Andalusians in the section on Mediterranean breeds.)

Rhode Island Red. The Rhode Island Red has a rather long, rectangular body. This breed was developed from matings of Red Malay

game cocks to the common hens of Rhode Island and from matings between rose-comb Brown Leghorns and mottled females.

The plumage color of the Rhode Island Red is a rich brownish red, which should be as even as possible over the entire surface and throughout all sections, except that the lower webs of the primaries are mostly black; the upper webs of the secondaries are partly black; and the tail coverts, sickle feathers, and main tail feathers are black. In the lower neck feathers of the female there is also a slight ticking of black. The undercolor of all sections in both sexes should be red and free from a dark or slaty appearance, which is known as "smut." The beak is reddish horn, and the shanks and toes are rich yellow or reddish horn.

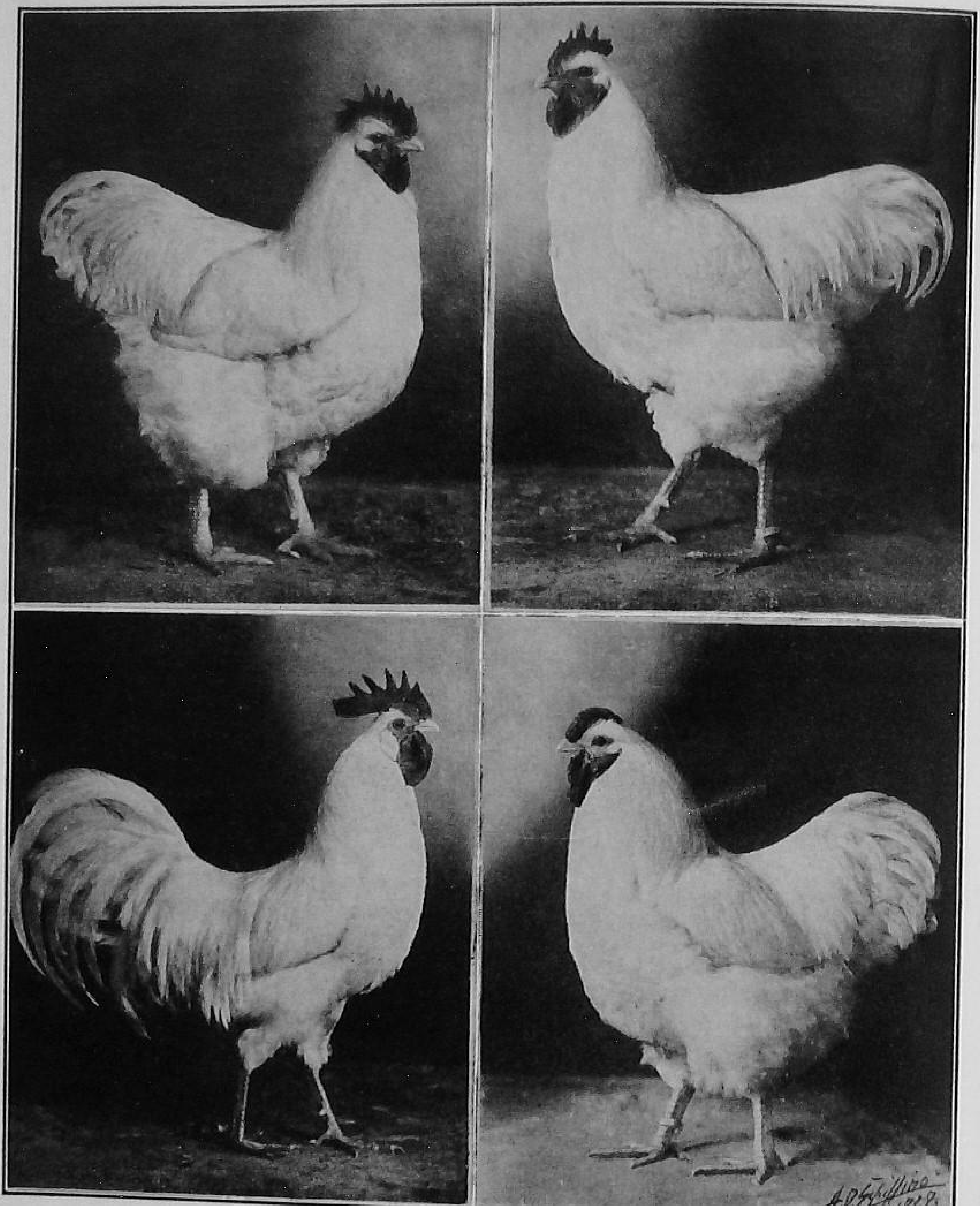
Rhode Island White. The Rhode Island White, of which the rose comb is the only variety, is identical in size and type with the rose-comb Rhode Island Red and was developed from White Wyandottes, Partridge Cochins, and rose-comb White Leghorns. The plumage should be pure white, free from any tint of brassiness.

New Hampshire. The New Hampshire breed was developed in New Hampshire from fast-growing, light-colored strains of Rhode Island Reds. The New Hampshire has a single comb. In shape of body the New Hampshire is less rectangular in shape than the Rhode Island Red. In the New Hampshire male the back is brilliant deep chestnut red, and the wing fronts, breast, body, and fluff are medium chestnut red. The saddle is brilliant chestnut red, and the main tail feathers are black, as are the lower webs of the primaries. The neck feathers are brilliant reddish bay.

In the New Hampshire female the neck, wing fronts, primary coverts, back, breast, body, and fluff are medium chestnut red. The lower neck feathers are distinctly tipped with black. The main tail feathers are black, edged with medium chestnut red. In both sexes the undercolor is light salmon.

Delawares. The Delawares represent one of the newest members of the American breeds. They were developed from selected progeny secured from crossing Barred Plymouth Rock males and New Hampshire females. The chicks that served as foundation stock of the breed that came to be recognized as Delawares were white in color at hatching time. As adults, they had white plumage except for black-and-white barring in the neck, wing, and tail feathers. Several years of selection and breeding for uniformity in plumage pattern resulted in the recognition of the Delawares as a breed. Rapid growth and fast feathering were given particular emphasis in the selection and breeding program.

The body is broad and deep, and the back is broad, sloping slightly from the saddle to the tail. The breast is deep and full.



Top, White Orpington
Bottom, S. C. White Leghorn

Top, White Plymouth Rock
Bottom, White Wyandotte

Fig. 18.

Wyandotte. The body of the Wyandotte is comparatively round, and the general shape and character of feathering give it an appearance of having a rather short back and being low set.

The *Silver Laced Wyandotte* was the first variety developed, principally from crosses between Buff Cochins and Silver Sebright Bantams and from crosses between Dark Brahmas and Silver Spangled Hamburgs. This variety has a striking color combination which makes it very attractive.

The male has a silvery-white hackle, back, and saddle, the hackle and saddle feathers being striped with black. The feathers of the body and breast are white, laced with a black edge. The primaries are black with the lower edges white; the secondaries are also black with the lower half of the outer webs white and the upper webs edged with white. The main tail feathers are black.

The female has white feathers laced with black over the entire body, except the neck feathers, which are black; there is also some black in the wings. The primaries and secondaries are practically the same as in the male. In both sexes the undercolor is slate. Other varieties of Wyandottes include the White, Buff, Black, Columbian, Golden Laced, Partridge, and Silver Penciled.

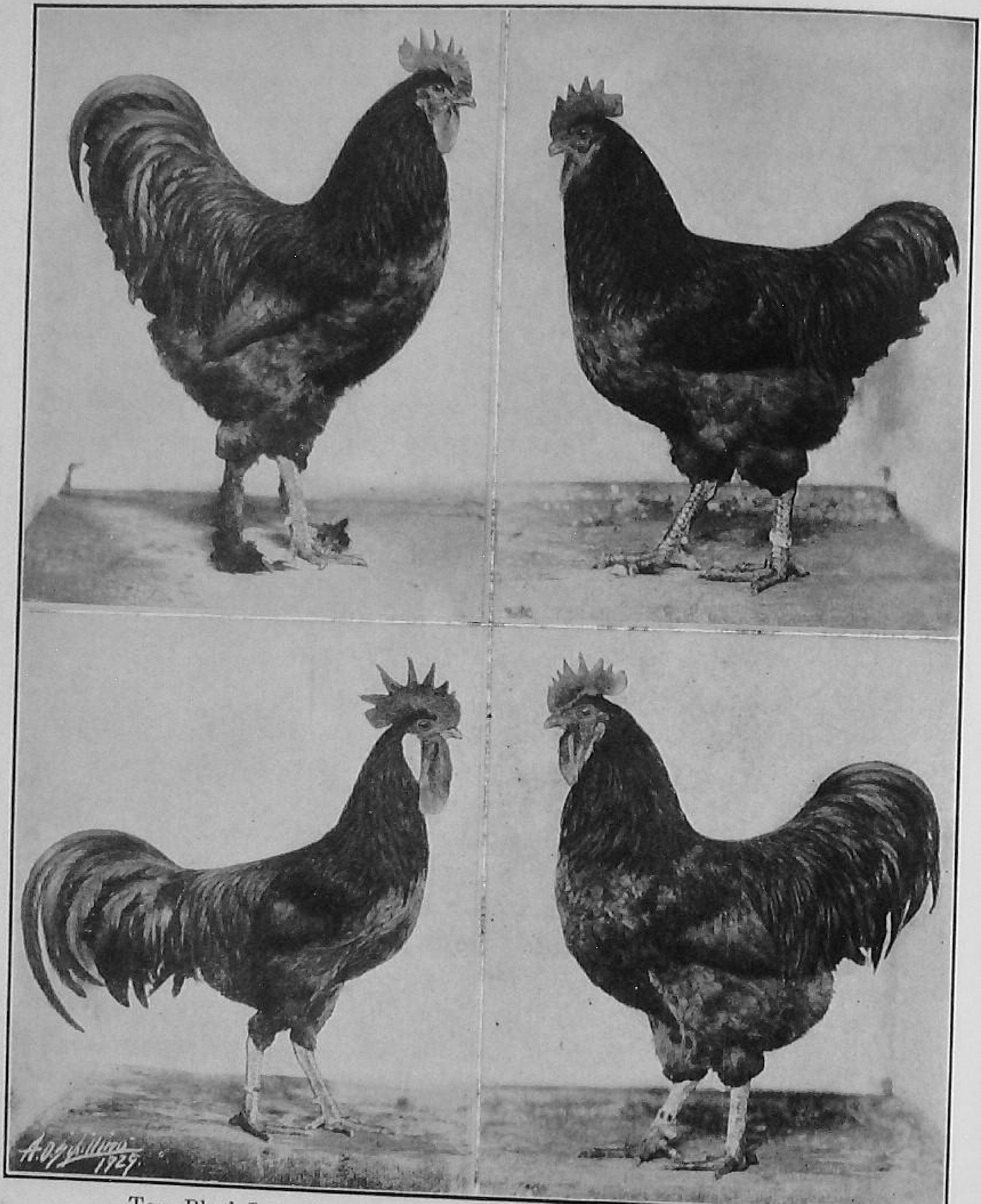
Other American breeds include the Jersey White Giant, Jersey Black Giant, Java, Buckeye, Lamona, Chanticler of Canadian origin, and Cubalaya of Cuban origin.

ASIATIC BREEDS

Of the three Asiatic breeds recognized as standard, the Brahma, Cochin, and Langshan, only the first two ever gained particular prominence in the American poultry industry. With the development of the American breeds, however, the popularity of the Asiatic breeds was not maintained, and they are now bred to a limited extent only.

The breeds belonging to the Asiatic class are of distinctive type and have large bodies, feathered shanks, and are usually heavy in bone. All have yellow skin, except the Black Langshan, whose skin is a pinkish white. All have red ear lobes, lay brown-shelled eggs, and are classed as broody.

The three Asiatic breeds include the Brahma, Cochin, and Langshan. There are three varieties of *Brahmas:* the Buff; the Light, which has the same color pattern as the Columbian Plymouth Rock; and the Dark, which has the same color pattern as the Silver Penciled Plymouth Rock. There are four varieties of *Cochins:* the Buff, Black, White, and the Partridge, which has the same color pattern as the Partridge Plymouth Rock. The *Langshan* varieties include the Black and the White.



Top, Black Langshan
Bottom, S. C. Black Minorca

Top, Jersey Black Giant
Bottom, Australorp

Fig. 19.

ENGLISH BREEDS

The breeds of English origin described in the "American Standard of Perfection" are, for the most part, utility breeds noted for their excellent fleshing properties. With the exception of the Cornish, all the breeds have white skin and red ear lobes and, except the Dorking and Red Cap, lay brown-shelled eggs. All are classed as broody.

The six English breeds include the Orpington, Australorp, Dorking, Sussex, Red Cap, and Cornish. The *Orpingtons* are characterized by their size and shape of body, which is long, deep, and well rounded, with a full breast and broad back. There are four varieties of Orpingtons, the Buff, Blue, Black, and White. The *Dorking* is a five-toed breed in which the body is long, broad, deep, and low set. There are three varieties of Dorkings, the White, Colored, and Silver Gray. The *Australorp* was developed in Australia from the Black Orpington but is more upstanding and less massive in appearance. In the *Sussex* breed the body is long, broad at the shoulders, and with good depth from front to rear. There are three Sussex varieties, the Light, whose color of plumage is quite similar to the Columbian Plymouth Rock, the Red, and Speckled. The *Red Cap* is a bird of medium size and has a rose comb. The *Cornish* is noted for its close feathering and compact, heavily meated body, which has a distinctive shape. The breast is very deep and broad, giving the shoulders great width. There are three varieties of Cornish, the Dark, White and White Laced Red.

MEDITERRANEAN BREEDS

The breeds of Italian origin are smaller than the Asiatic breeds, and in America the White Leghorns especially have been bred for egg production rather than for the production of table poultry. The breeds of Spanish origin are somewhat larger than the Leghorns and Anconas. All the Mediterranean breeds have nonfeathered shanks, white or creamy-white ear lobes, lay white-shelled eggs, and are relatively nonbroody.

Leghorn. The Leghorn is noted for the graceful blending of its different sections and its stylish carriage. All the varieties of Leghorns have yellow beaks, skin, shanks, and toes. There are single-comb and rose-comb varieties.

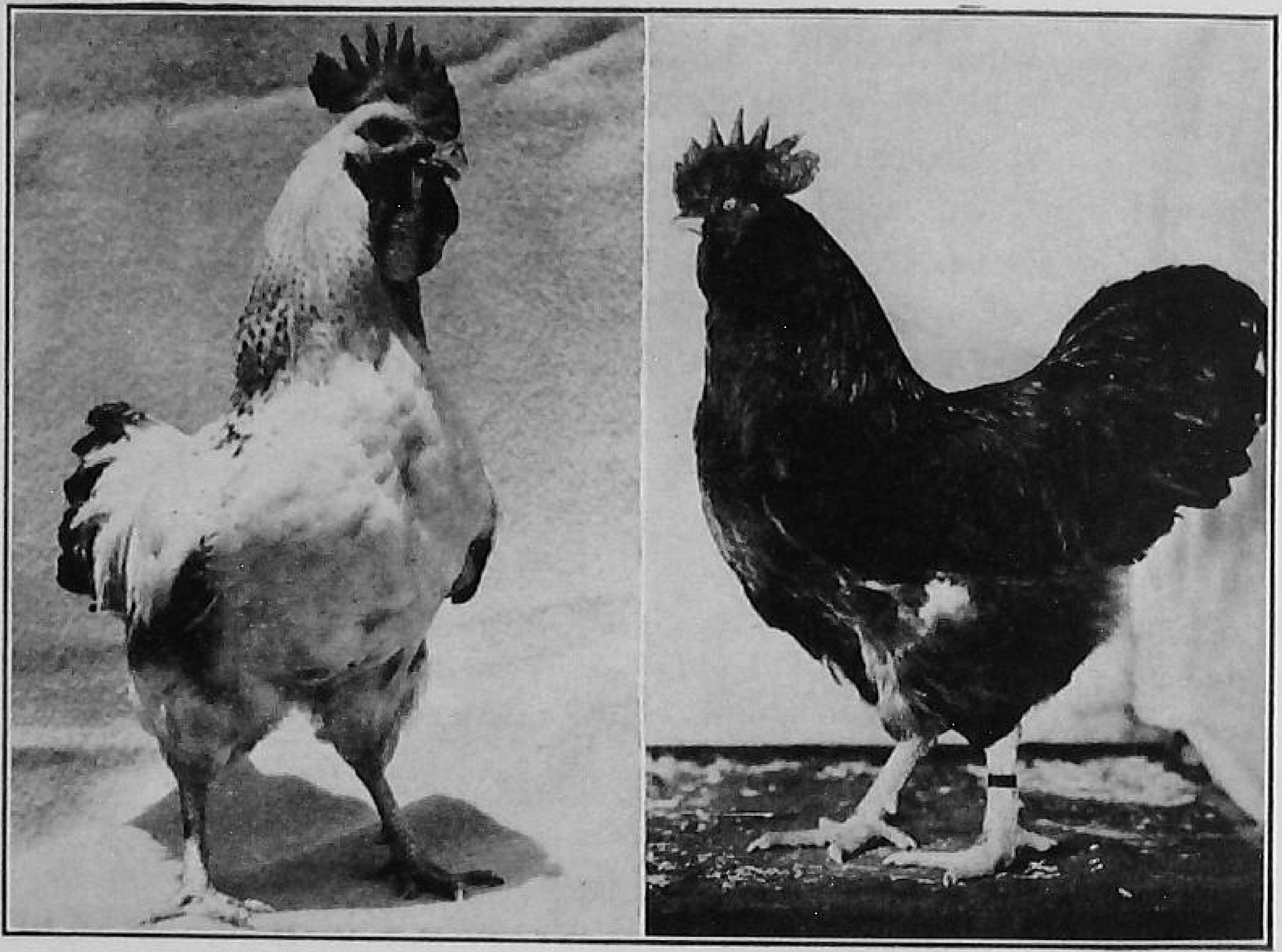
The single comb in the male should be of medium size and should stand erect, with five regular, deeply serrated points, the back of the comb extending straight out from the back of the head. In the female the front of the first point should stand erect, but the remainder of the comb should droop to one side. The comb in both sexes should be free from wrinkles, "thumbmarks," or folds.

In the rose-comb variety the comb of the male should be of medium size and square in front, well filled and free from hollows, the spike well developed and extending straight back from the head. In the female the comb is small, neat, and in shape is like that of the male.

There are 12 varieties of Leghorns, the Buffs, Blacks, Reds, Silvers, Columbians, and Black-tailed Reds having single combs only, whereas

there are single-comb and rose-comb subvarieties of the Whites, Dark Browns, and Light Browns.

Ancona. The Ancona resembles the Leghorn in type and has black plumage except for certain feathers with a white tip. Over the back and saddle of males, one feather in five is tipped with white; over the back of females, one feather in about two is tipped with white. Over the breast, body, and fluff in both sexes, one feather in about two is tipped with white.



Delawares New Hampshire

Fig. 20.

Minorca. The Minorca is the largest of the Mediterranean breeds and is noted for its length of body, downward sloping back, and large comb and wattles. The varieties include: Blacks and Whites, each with single- and rose-comb subvarieties, and the Single-comb Buff.

White Faced Black Spanish. This breed has a very extensive white face, the body type being similar to the Minorca.

Blue Andalusian. The color of this breed is similar to that of the Blue Plymouth Rock. The Blue Andalusian has not been bred extensively for egg production, but is of interest particularly with respect to the inheritance of its blue plumage.

The progeny of Blue Andalusian male and female parents comprise three groups in the following proportions: 1 black to 2 blue to 1 white, splashed with blue. Black males and females mated together produce

blacks, and blue-splashed white males and females mated together produce blue-splashed whites. Typical Blue Andalusians result from matings of opposite sexes of blacks and blue-splashed whites, as well as (for one-half of the progeny) when Blue Andalusian males and females are mated together, as explained above.

Buttercup. The two outstanding features of this breed are its cup-shaped comb and the golden ground color of its plumage.

OTHER BREEDS

Among several Continental European breeds, the Houdan, La Flèche, Faverolles, and Crèvecoeur are of French origin, but none of them has become popular in the United States. The Campine is of Belgian origin and includes the Silver and Golden varieties. Interest in the Campine lies largely in the fact that the males are hen feathered, the hackle, saddle, and lesser tail feathers being of the same shape as in the female. There are several varieties of the Polish breed, its outstanding feature being a well-developed crest surmounting the head. There are also several varieties of the Hamburg breed, an outstanding character being the upturned spike of its rose comb. There are numerous varieties of the Game breed, bred to a limited extent only by fanciers.

Three miscellaneous breeds recognized as standard in America include the Frizzle, with its peculiar development of the feathers which show a tendency to curve outward at their ends; the Silkie, with its blue skin and silky-appearing feather formation; and the Sultan, with its V-shaped comb, a crest, muffs, beard, and vulture hocks.

The Phoenix or Yokohama, of Japanese origin, is interesting because some of the saddle feathers are developed to extreme length, sometimes as long as 20 ft. The Araucana, of South American origin, is of interest because it has a peculiar growth of feathers on each side of the neck, is frequently rumpless, and lays a light-blue-tinted egg. The Creeper is noted for its extremely short legs. There are numerous breeds of bantams, of interest to fanciers only.

DEFECTS AND DISQUALIFICATIONS

Very few birds attain perfection in type, plumage color, and other characters. Imperfections are classed as defects or disqualifications, the latter barring a bird from winning a prize in a poultry show where the "Standard of Perfection" is used as the basis of judging the entries.

Defects include such things as too few or too many points on single combs, color of eyes other than as described for the breed, crooked toes and keels, creaminess in plumage of white varieties, and black feathers in Barred Plymouth Rocks.

Disqualifications include such things as deformed beaks, side sprigs in single-comb varieties, positive enamel white in the ear lobe of American and Asiatic varieties, and decided bowleggedness or knock-kneedness.

In the selection of breeding stock, disqualifications and defects of major importance should always be kept in mind, especially those that are inherited.

TABLE 6. STANDARD WEIGHT IN POUNDS OF SOME REPRESENTATIVE BREEDS

Breed[a]	Cock	Hen	Cockerel	Pullet
Ancona	6	4½	5	4
Australorp	8½	6½	7½	5½
Brahma (Light)	12	9½	10	8
Cornish (Dark)	10	8	8½	6½
Delawares	8½	6½	7½	5½
Jersey Black Giant	13	10	11	8
Leghorn	6	4½	5	4
Minorca (S. C. Black)	9	7½	7½	6½
New Hampshire	8½	6½	7½	5½
Orpington	10	8	8½	7
Plymouth Rock	9½	7½	8	6
Rhode Island Red	8½	6½	7½	5½
Sussex	9	7	7½	6
Wyandotte	8½	6½	7½	5½

[a] All the breeds listed lay brown-shelled eggs, except the Ancona, Leghorn, and Minorca. All these breeds have nonfeathered shanks, except the Brahma.

TABLE 7. TYPE OF COMB AND IMPORTANT COLOR CHARACTERISTICS OF SOME REPRESENTATIVE BREEDS

Breed[a]	Type of comb	Color of ear-lobe	Color of skin	Color of shanks
Ancona	Single and rose	White	Yellow	Yellow
Australorp	Single	Red	White	Dark slate
Brahma (Light)	Pea	Red	Yellow	Yellow
Cornish (Dark)	Pea	Red	Yellow	Yellow
Delawares	Single	Red	Yellow	Yellow
Jersey Black Giant	Single	Red	Yellow	Black
Leghorn	Single and rose	White	Yellow	Yellow
Minorca (S. C. Black)	Single	White	White	Dark slate
New Hampshire	Single	Red	Yellow	Yellow
Orpington (Buff and White)	Single	Red	White	White
Plymouth Rock	Single	Red	Yellow	Yellow
Rhode Island Red	Single and rose	Red	Yellow	Yellow
Sussex	Single	Red	White	White
Wyandotte	Rose	Red	Yellow	Yellow

[a] See footnote to Table 6.

RELATIVE POPULARITY OF BREEDS

In spite of the fact that there are so many different breeds and varieties, most of the purebred chickens kept in the United States belong to the following five breeds: Plymouth Rocks, Rhode Island Reds, New Hampshires, Wyandottes, and Leghorns. Delawares are increasing in numbers. There are no varieties of the New Hampshire breed, but among the other four breeds the following varieties are by far the most important: Barred Plymouth Rocks, White Plymouth Rocks, Single-comb Rhode Island Reds, White Wyandottes, and Single-comb White Leghorns. It is interesting to note that among these six varieties, three have white plumage, which presents a much simpler problem in breeding than is the case with most parti-colored breeds and varieties. Also, among the parti-colored breeds and varieties, it is easier to produce birds that meet approximate standardbred plumage requirements in Barred Plymouth Rocks, New Hampshires, Rhode Island Reds, and Delawares than in varieties having laced, penciled, and other complex plumage patterns.

White Leghorns are suitable primarily for market-egg production, and the other popular varieties, plus the New Hampshire breed, are kept primarily for egg and meat production. New Hampshires, White Plymouth Rocks, Barred Plymouth Rocks, and Delawares have been used extensively in broiler production.

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CHAPTER 3

THE BIOLOGY OF THE CHICKEN

In the preceding chapter various breeds and varieties of chickens were described on the basis of their external appearance. External characteristics, however, provide practically no information concerning the internal structure of the chicken or how it digests food and produces eggs. These and many other processes that have practical application in the poultry enterprise are of interest to students of poultry husbandry. An understanding of how various functions are performed within the chicken's body makes it easier to understand why certain practices are recommended in the following chapters.

From the structural standpoint the chicken is an interesting creature. In common with other birds, it possesses feathers, has a breastbone, and spurs, but lacks teeth. It has a comb, which sets it apart from other birds.

In comparison with most of the other domestic animals used for the production of food for mankind, the chicken is a short-lived creature. It is a rapid breather, has a pulse rate of about 300 to 370 beats per minute, and digests its food relatively quickly. The body temperature is higher than that of other domestic animals, averaging about 106°F., with variations between day and night temperatures.

THE BODY COVERING

The skin and feathers constitute the body covering of the chicken and serve as protective features.

The Skin. So long as the skin is not injured, it offers a considerable degree of resistance to millions of disease organisms present on most poultry premises. The skin has no glands except a preen gland or so-called "oil gland" at the base of the tail. Two layers comprise the skin, the outer one being called the "epidermis" and the inner one the "dermis." The beak, scales on the shanks, and the feathers develop from the epidermis. The comb, wattles, and ear lobes develop from the dermis and are covered by the epidermis. The size and texture of the comb and wattles serve a practical purpose in determining whether or not a hen is in laying condition, as pointed out in a later chapter.

Yellow shank color, in all American and some other breeds, is due to

the presence of a fat or lipochrome pigment in the epidermis, black or melanic pigment being absent in both epidermis and dermis. Black shank color is due to the presence of melanic pigment in the epidermis. White-color shank, in several English breeds, is due to the absence of both types of pigment in the epidermis and dermis. Light-blue and dark-blue shank color in white-skinned breeds is due to the presence of melanic pigment in the dermis, neither the melanic nor the lipochrome pigment being present in the epidermis. Green shank color is due to the presence of lipochrome pigment in the epidermis and melanic pigment in the dermis. In females having yellow shanks, it is possible to estimate the approximate time in egg production by the shade of shank color, the lipochrome pigment being diverted from the feed to the yolks as egg production increases instead of going to the shanks. This factor in relation to culling laying flocks is discussed in a later chapter.

Feathers. Having feathers differentiates birds from all other animals. Feathers conserve body heat in cold weather and protect the bird against bodily injury. In addition, the condition of the feathers often serves to indicate whether a bird is sick or healthy. In certain breeds and varieties, changes in the color or color pattern of the feathers serve as an index of certain nutritional deficiencies in the diet.

Since feathers serve as insulation, and since heat loss is roughly proportional to the surface area of the body, it is interesting to observe that the weight of feathers bears a closer relationship to body weight than does the number of feathers. Feathers in large-sized birds tend to be larger than in small-sized birds. Neither the weight nor the number of feathers serves as a satisfactory index of the insulating or thermoregulatory capacity of feathers. In American breeds the weight of feathers apparently varies from about 4.5 to about 6.0 per cent of live body weight. The number of feathers on birds of most American breeds varies from about 6,000 to about 8,000, some Wyandottes having over 9,500 feathers.

The early growth of the primary and secondary wing feathers in chicken embryos is of practical importance in developing strains of broilers that feather rapidly and have few pinfeathers at marketing time. This problem is discussed in a later chapter.

Under normal conditions, a laying hen usually undergoes her first complete annual molt at the conclusion of her first year of laying. The time and duration of the first annual molt are important factors in identifying the best layers, as pointed out in another chapter.

Feathers Arise from Feather Tracts. Although feathers cover practically all parts of the body, they arise from certain defined areas of the skin called "feather tracts" or "pterylae." There are 10 of these feather tracts, feathers developing in the tracts approximately in the following

order: shoulder, thigh, rump, breast, neck, abdomen, leg, back, wing, and head. The first indications of feather track appear during the fifth day of embryonic development.

There is one breed, the Transylvania Naked-Neck, that differs from all other breeds in having practically no feathers on the neck. This is only mentioned here because some poultrymen have introduced this

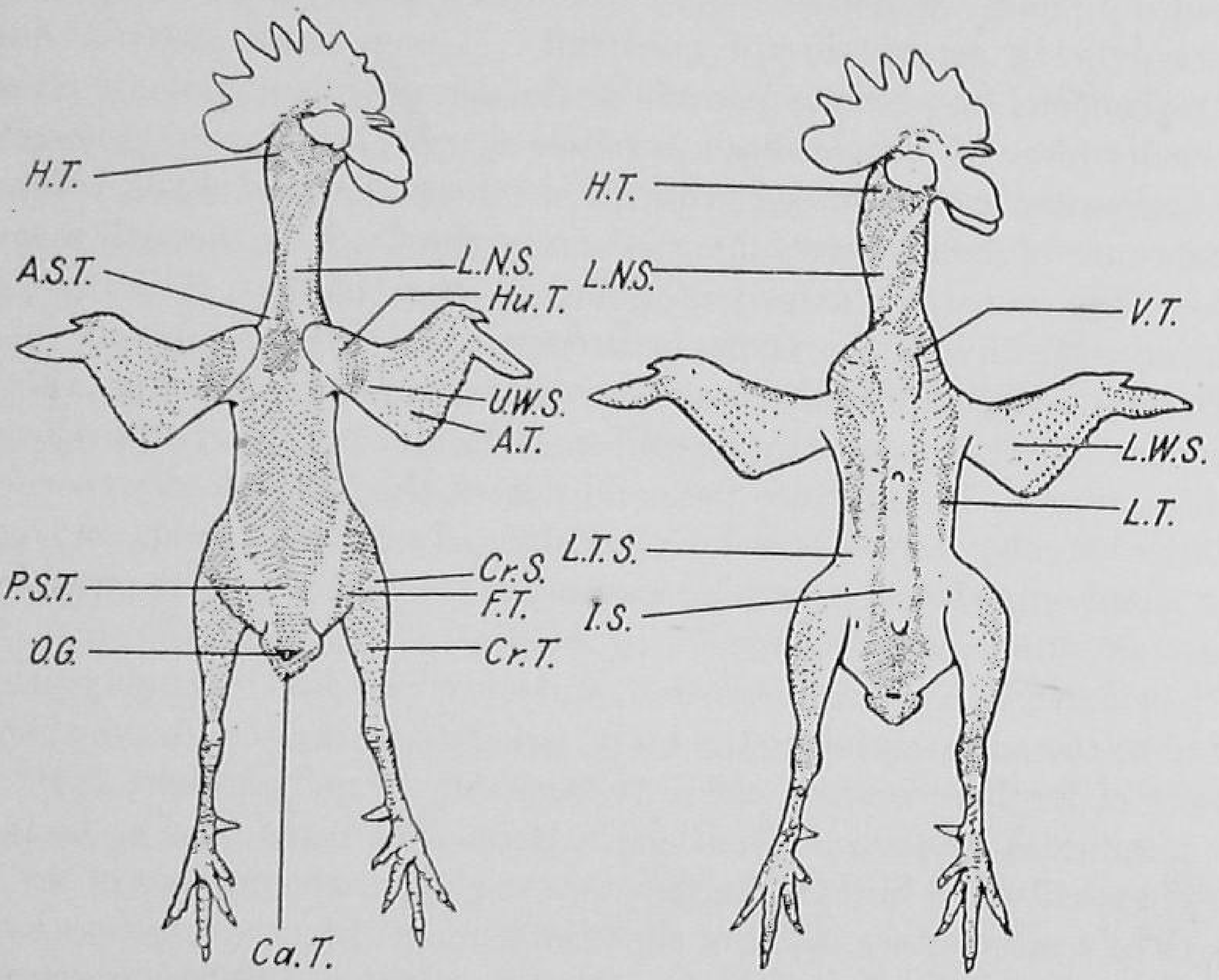

FIG. 21. Left, feather tracts and bare spaces (apteria) between tracts on the dorsal side of a bird. Right, feather tracts and apteria on the ventral side of a bird. A.T., alar tract; A.S.T., anterior spinal tract; Ca.T., caudal tract; Cr.T., crural tract; Cr.S., crural space; F.T., femoral tract; H.T., head tract; Hu.T., humeral tract; I.S., inferior space; L.N.S., lateral neck space; L.T., lateral tract; L.T.S., lateral trunk space; L.W.S., lower wing space; O.G., oil gland; P.S.T., posterior spinal tract; U.W.S., upper wing space; V.T., ventral tract. (*A. W. Greenwood.*)

peculiar characteristic into their strains and falsely represented the stock as being a cross between the turkey and the chicken.

Feather Growth and Structure. During the fifth day of embryonic development, feather papillae appear. Each feather begins its growth in a follicle, a depression in the skin of the embryo. These follicles develop before hatching time and give rise to chick down. Later, as the true feathers arise from these follicles, the down is pushed out by the growing feather. Each feather has its origin in a feather germ at the base of the follicle. All growth of the feather germ takes place in its basal portion. This causes successive sections to be pushed upward and

outward so that in a few days the developing feather germ is visible above the skin. This is the pinfeather stage, the feather being completely enclosed in a sheath. Very soon thereafter the feather breaks through the tip of the sheath and unfurls.

The nutrition of the growing feather takes place through the pulp, a highly vascular cylindrical organ surrounded by the different parts of the young feather and the sheath. The pulp is longest in the pinfeather stage and becomes shorter as the feather continues growing. In the fully grown feather the pulp is completely absent.

A fully grown feather consists of the quill, which extends throughout the feather as the shaft or rachis; the barbs branching out on each side of the shaft; barbules branching out on each side of the barbs; barbicels

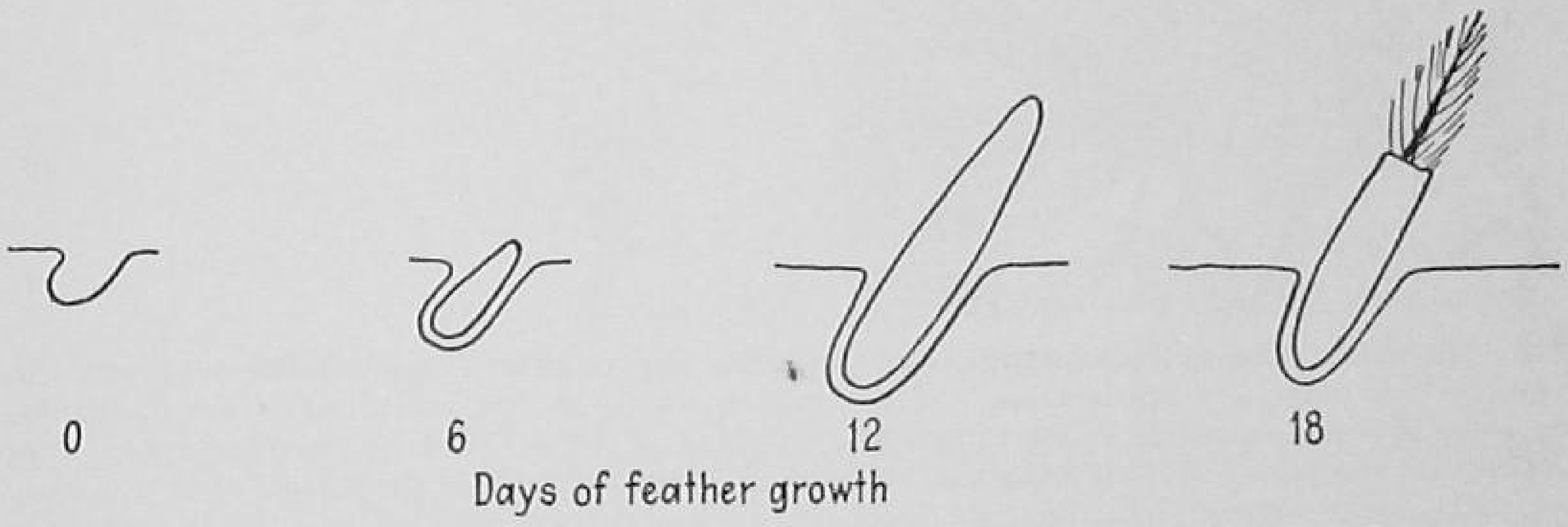

FIG. 22. Schematic representation of the growth of a regenerated feather following the plucking of the original feather. The depression in the surface of the skin, the follicle, is shown at *O*. The organization and growth of the pinfeather at about 6 days of growth is shown at 6. The emergence of the pinfeather beyond the surface of the skin at about 12 days of growth is shown at 12. The feather breaking through at the tip of the sheath and unfurling at about 18 days of growth is shown at 18. (*Mary Juhn, University of Maryland.*)

branching out on each side of the barbule. Some of the barbicels have hooklets that serve to hold the interlocking barbules in place, thus giving strength to the barbs and the feather as a whole.

In the males of most breeds, the neck, saddle, and sickle feathers are longer and more pointed than in females and are called "secondary sexual" feathers. In certain breeds, such as Campines and Sebrights, these feathers in males are the same shape as in females, these breeds being called the "hen-feathered" breeds.

The coloration of feathers is due to the presence of pigments. The first pigment cells, melanoblasts, are formed in the embryo at about 80 hr. of incubation. The melanoblasts enter the feather germ where they acquire pigment and are then known as "melanophores." During the course of feather development, these pigments are transferred to barbules, barbs, and shafts. Plumage patterns seen in different varieties of chickens are due to the presence of different kinds of pigments, the shape of the pigment cells, the shape of the feathers, and by other factors.

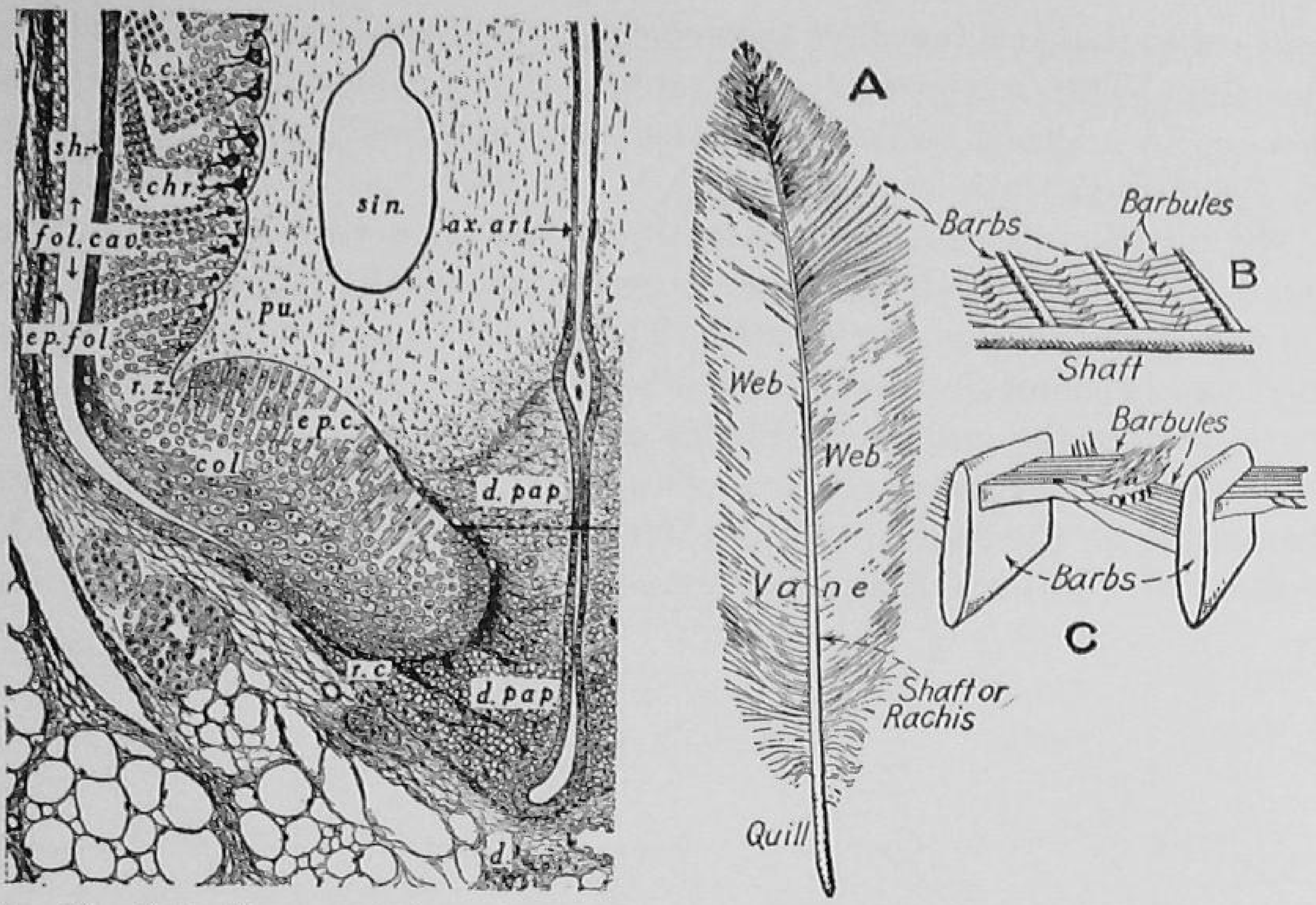

FIG. 23. Left, diagram of the region of the collar and papilla corresponding to about the twenty-first day of regeneration. The relative width of the collar and the epidermal cylinder is exaggerated in order to bring out details of cells. The broken horizontal line represents the plane of rupture across the papilla when the regenerating feather is plucked. ax. art., axial artery; b.c., barbule cells; chr., chromatophores; col., collar; d., derma; d. pap., dermal papilla; ep. c., columnar epithelium of collar with elongated nuclei; ep. fol., epidermis lining wall of follicle; fol. cav., cavity of follicle; sin., blood sinus; pu., pulp; r. c., regeneration cells; sh. sheath. (*F. R. Lillie and Hsi Wang.*) Right, the structure of the feather. (*Evans.*)

THE SKELETAL SYSTEM

The skeleton of the chicken is very light in weight, but is very strong. The bones are especially rich in calcium salts and are thus very dense. There are 13 or 14 cervical vertebrae, and in the thoracic region of the vertebral column there are 7 vertebrae. Several of the coccygeal vertebrae are fused to form the last segment of the coccygeal group. This segment is called the "pygostyle," the last bone being called the "urostilus." The pygostyle forms the skeletal support for the feathers of the tail.

The chicken has seven pairs of ribs. The sternum is long and broad and supports the viscera.

Of practical interest to flock owners is the relative position of the two pubic bones to each other and the relative distance between the ends of the pubic bones and the posterior end of the sternum in hens that are in laying condition as compared with hens that are not in laying condition. When a hen is in laying condition, the pubic bones are spread far apart and there is a considerable space between the ends of the pubic bones and

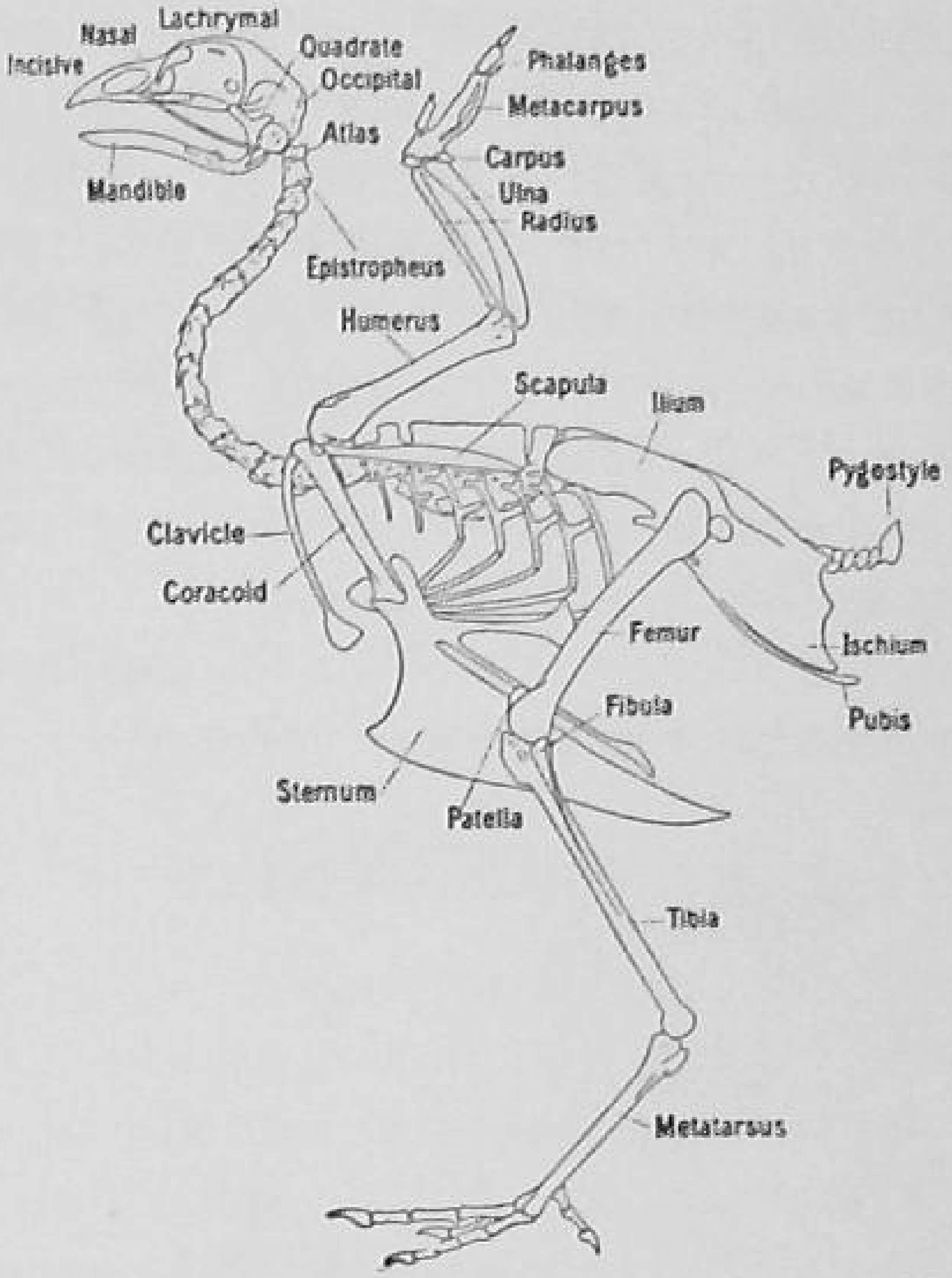

FIG. 24. The skeleton of a fowl. (*O. Charnock Bradley.*)

the end of the sternum. This factor is of practical use in culling laying flocks.

THE MUSCULAR SYSTEM

The chicken has a very complex muscular system, but there are only a few details of interest to students of poultry husbandry. The breast or pectoral muscles are the largest of all the muscles, and besides enabling the bird to raise and lower its wing, sometimes provide the largest share of meat obtained from a chicken. Suggestions are made in a subsequent chapter concerning breeding methods to follow in developing strains with better fleshed breasts.

THE RESPIRATORY SYSTEM

The lungs in birds are fastened dorsally to the ribs and are inexpansible. Gaseous exchange takes place primarily with breathing out or expiration. Associated with the lungs of chickens are the air sacs, which communicate directly with the cavities of several of the long bones of the wings and legs.

In birds the lungs are small in proportion to body size. In front, the lungs are limited by a false diaphragm so that they are relatively non-expansible. The trachea divides into two mesobronchi, which open into the abdominal and posterior thoracic air sacs on each side of the bird's body.

Inspiration begins as a result of increasing carbon-dioxide tension in the blood. During inspiration, air enters the air sacs as a result, to some extent, of the bellowslike action of the air sacs, some gaseous exchange taking place. During expiration, the air is driven from the air sacs, the major portion of the gaseous exchange being completed. A respiratory reflex, which begins as a passive movement, is present and acts chiefly to promote expiration. The passage of the expired air up the trachea results in the forceful expulsion of the air. The expiratory phase lasts about twice as long as the inspiratory phase.

The syrinx, located at the division of the trachea into the two bronchi, is the organ responsible for the chicken's voice.

THE NERVOUS SYSTEM

The nervous system of the chicken consists of the brain, spinal cord, sympathetic nerves controlling the viscera, and branches leading to the eyes and ears. The brain and the spinal cord are quite similar in structure to those in mammals. A condition known as "limberneck" in chickens is due to a paralysis of the nerves, and a common disease known as "fowl paralysis" or "neurolymphomatosis" is often associated with a thickening of the sciatic nerve.

THE CIRCULATORY SYSTEM

The blood and lymph circulatory systems perform very important functions. The blood circulatory system transfers digested nutrients from the food, water, oxygen, and carbon dioxide to and from the body cells. The lymph circulatory system consists of a network of tiny, transparent vessels that transport the lymph to lymph nodes located throughout the body. These lymph nodes produce lymphocytes, a type of white corpuscle, which is an important disease-fighting unit in the blood. The lymph nodes also trap bacteria and salvage vital proteins, which would otherwise be lost.

The Blood. The blood constitutes about 8 to 10 per cent of a bird's body weight and is comprised of a liquid portion called plasma and blood cells. The two principal kinds of blood cells are the red cells or erythrocytes and the white cells or leucocytes.

The erythrocytes are relatively small, and each contains a nucleus, thus differing from the red-blood cells of mammals. They are formed principally in the bone marrow. The chief function of erythrocytes is to transport oxygen from the lungs to the body cells, which is accomplished by means of the blood's hemoglobin, an iron-containing protein. In male chickens the average number of red-blood cells is larger than in

female chickens. In females the number decreases immediately prior to and during laying.

The white-blood cells are larger than the red-blood cells, fewer in number, and are divided into several different groups. White-blood cells function in the defense mechanism against bacterial invasion.

THE DIGESTIVE SYSTEM

The digestive system of the chicken consists of the organs directly concerned in the reception of feed, its passage through the body, diges-

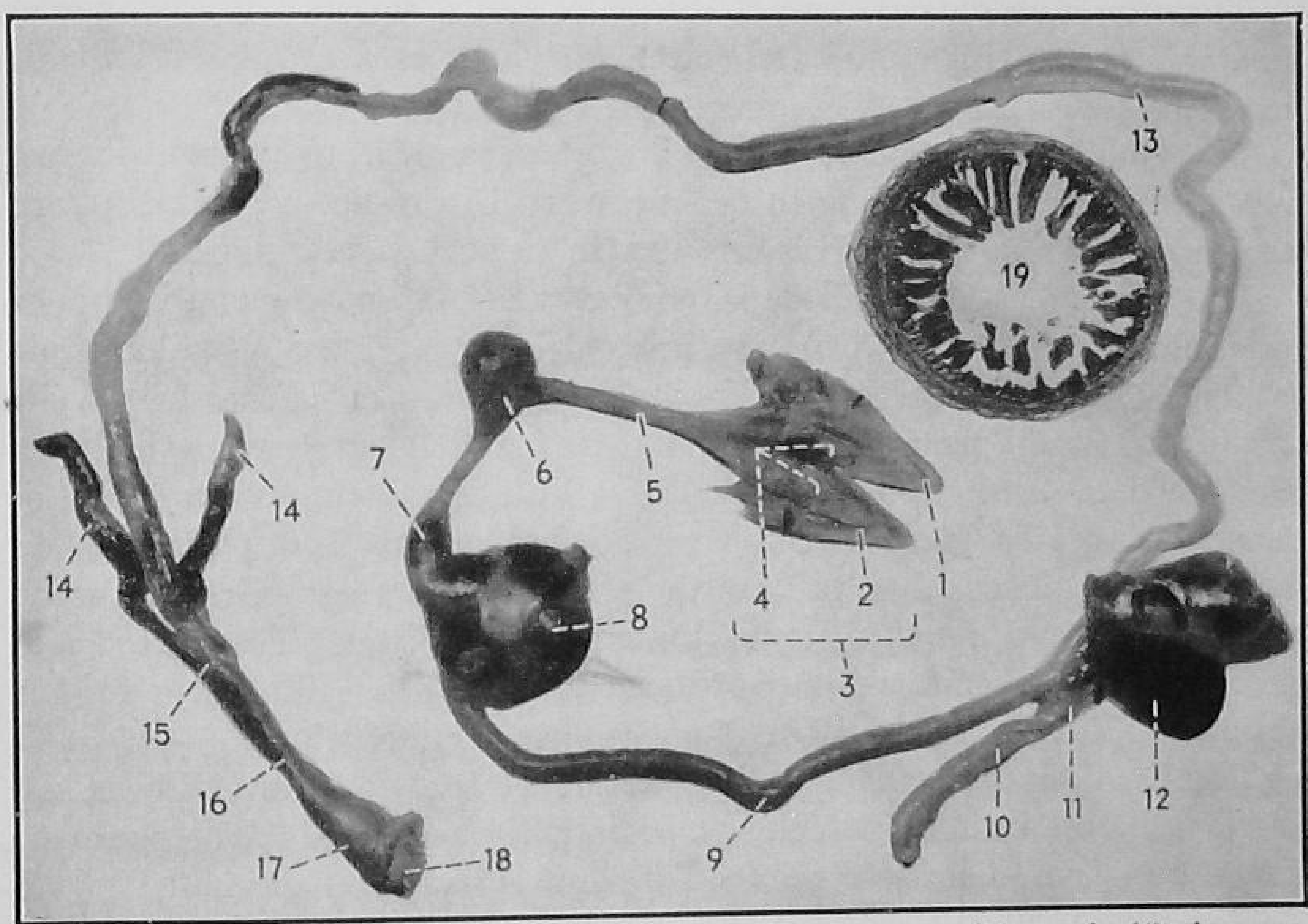

Fig. 25. The digestive tract of the chicken. (1) beak; (2) tongue; (3) mouth; (4) pharynx; (5) esophagus; (6) crop; (7) proventriculus; (8) gizzard; (9) duodenum; (10) pancreas; (11) gall bladder; (12) liver; (13) small intestine; (14) caeca; (15) junction of small intestine and caeca; (16) rectum; (17) cloaca; (18) anus; (19) cross section of small intestine showing villi, which increase the capacity to absorb nutrients. (*M. Lois Calhoun.*)

tion, and the excretion of waste products. The digestive system includes the alimentary canal and the accessory organs, the beak, tongue, liver, spleen, and pancreas. The alimentary tract includes the mouth, gullet, crop, glandular stomach, gizzard, small intestine, caeca, rectum, cloaca, and anus. Some knowledge of the gross anatomy of these different parts is of interest to students of poultry husbandry in order to more fully understand how the nutrients in the feed are converted into eggs, bone, muscles, and feathers. Also, since an examination of some of the internal

organs is necessary for the proper diagnosis of certain diseases, it is well to know the normal condition of these organs.

The Beak and Tongue. The beak consists of the upper and lower mandible. The tongue is pointed and has barblike projections at its rear to enable feed particles to be forced back toward the entrance of the gullet.

The Gullet and Crop. The gullet, or esophagus, is an elastic tube leading from the pharynx at the floor of the mouth to the crop and from the crop to the proventriculus. The gullet is lubricated internally by mucous glands.

The crop is an enlargement of the gullet and serves as a storage pouch in which the food is stored and softened as long as the proventriculus is in action.

The Glandular Stomach. The glandular stomach, or proventriculus, is a thickened tube leading to the gizzard. During its passage through the proventriculus the food is mixed with an acid gastric juice.

The Gizzard. The oval-shaped gizzard has two openings on its upper side, one of which leads from the proventriculus and one of which leads to the duodenum, a section of the small intestine. The gizzard is a very important organ serving to grind the feed and in some respects takes the place of teeth in other animals. With its thick development of musculature, the gizzard grinds or crushes coarse feed particles and breaks down the cellulose walls of the grains. The presence of grit in the gizzard increases the efficiency of the grinding process. The particles of grit remain in the gizzard until reduced to a fine ash. When the food is ground to a homogenous mass, it passes into the duodenum.

The Small Intestine. The first section of the small intestine is the duodenal loop, inside of which is contained the pancreas. The pancreas pours digestive juices into the food while it is in the duodenum.

The digestion of food particles is completed in the small intestine. While the food is in the coiled portion of the small intestine, the absorption of the digested food takes place. Lining the inside of the small intestine are innumerable small structures called "villi," which increase the absorptive surface of the small intestine several times. The total length of the small intestine is about 5 ft., in some birds even longer.

The Liver. From the liver two ducts convey bile to the terminal part of the duodenum, the alkaline bile neutralizing the acids, the food thus being prepared for the action of the digestive enzymes. The bile is stored in the gall bladder.

The Spleen. The spleen is a small, roundish-shaped organ located at the juncture of the glandular stomach, gizzard, and liver. It is reddish brown in color, but the function it serves is not definitely known.

The Caeca. Two blind pouches, the caeca, each about 6 in. long, are located at the juncture of the small intestine and the rectum, or large intestine.

The Rectum, Cloaca, and Anus. The rectum is much shorter than the small intestine, being about 4 or 5 in. long. The rectum serves as a receptacle for fecal matter until it is ready to be excreted into the cloaca. The cloaca is divided into three parts: the coprodaeum, the urodaeum, and the proctodaeum. The ureters and genital tracts enter on the floor of the urodaeum. From the cloaca the fecal matter passes to the anus.

The Urinary System. Two kidneys and the ureters comprise the urinary system. Each of the kidneys consists of three lobes of unequal size. The kidneys are located along the vertebral column posterior to the lungs. From each kidney the urine, in the form of uric acid, a white pasty material, passes through the ureter to the cloaca, where it is subsequently voided with the fecal matter from the rectum.

THE REPRODUCTIVE SYSTEM

The various organs and structures previously described are similar in males and females. The male and female reproductive systems, however, differ markedly. This is to be expected, of course, because they produce male and female reproductive cells, respectively.

The Male Reproductive System. The reproductive system of the male consists of the primary and accessory sexual organs, only the former being involved in the production of the male reproductive cells. The primary sexual organs are called "gonads," and they consist of a pair of testes, or testicles, from each of which there is a tube called the "vas deferens," leading to the cloaca, the vas deferens being the accessory sexual organ.

The testes are situated at the anterior ends of the kidneys and are small yellowish-colored bodies, sometimes pigmented. The left testis is usually larger than the right one. Each testis consists of a large number of slender tubes, called "seminiferous tubules," from the linings of which the reproductive cells are given off, whence they are conducted by the epididymis to the vas deferens. It is while the spermatozoa are in the vas deferens that they acquire the power of motility.

Each vas deferens leads to a small projection or papilla located in the dorsal wall of the cloaca. The rudimentary copulatory organ of the male is located on the median ventral portion of one of the transverse folds of the cloaca.

The Female Reproductive System. The reproductive system of the female consists of primary and accessory sexual organs, the ovary and the oviduct, respectively. The ovary is involved in the production of

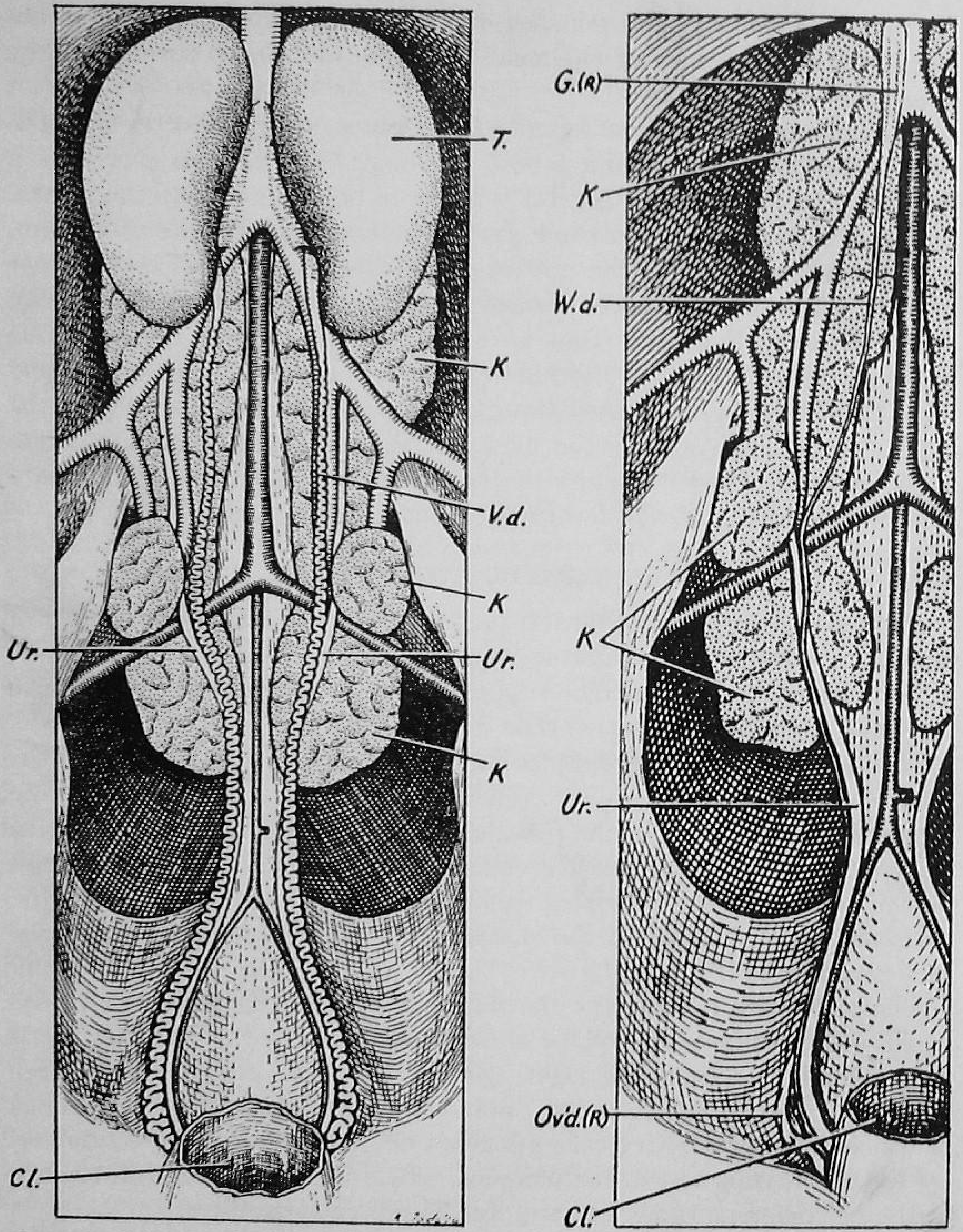

FIG. 26. Left, reproductive and urinary organs of the male fowl. Cl., cloaca; K., kidney; T., testis; Ur., ureter; V.d., vas deferens. Right, right side of female, showing rudimentary right gonad, oviduct, and urinary system. Cl., cloaca; G(R), right rudimentary gonad; K, kidney; Ovd.(R), rudimentary right oviduct; Ur., ureter. (*L. V. Domm.*)

the female reproductive cells, called "ova." The oviduct serves to carry the ova from the ovary to the cloaca. During the passage of the ova through the oviduct, the secretion of the different kinds of albumen or white of the egg takes place, as well as the shell membranes and shell to make the completed egg.

The ovary, or female gonad, is single and is on the left side of the body, although during embryonic development a right gonad and oviduct also develop but gradually degenerate until at hatching time only rudiments remain. Occasionally birds are observed that have two functional ovaries and oviducts.

In a typical female the ovary is situated to the left of the median line of the body just posterior to the lungs and at the anterior end of the

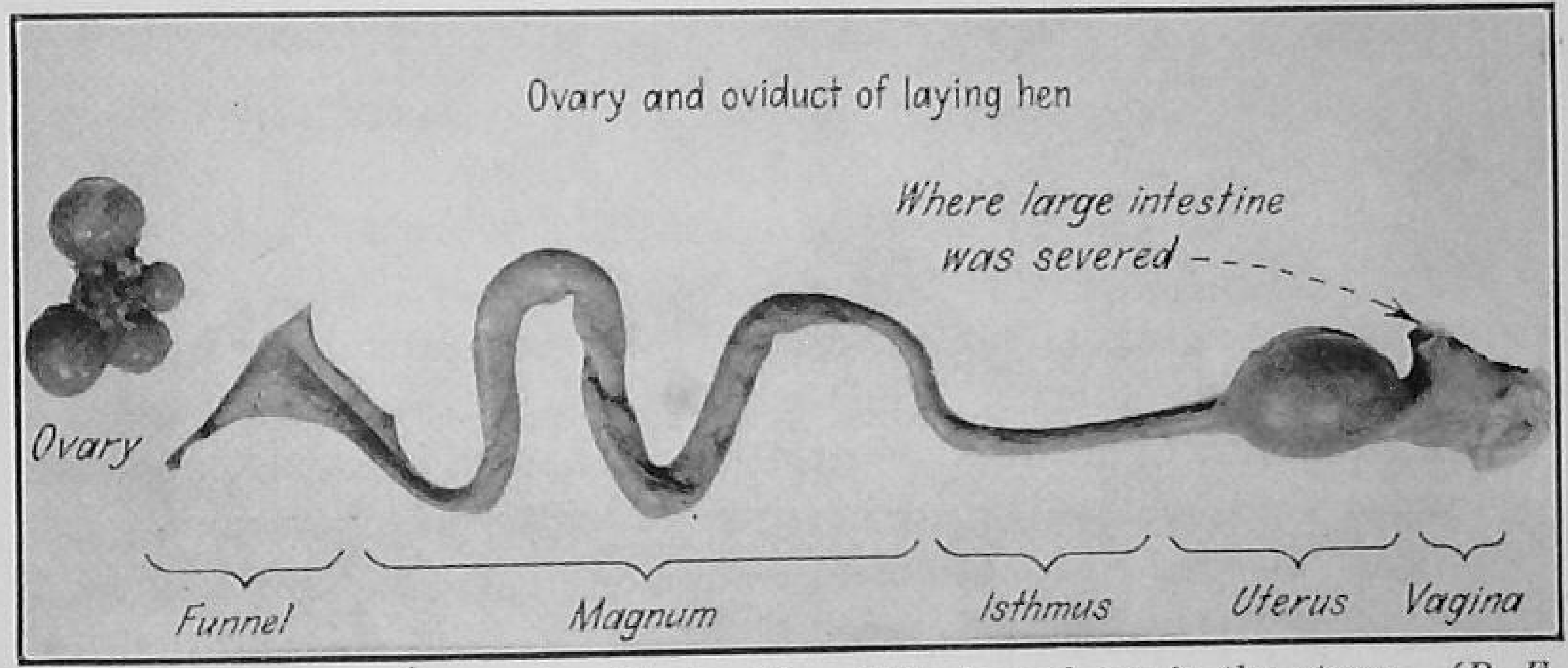

Fig. 27. The left ovary and oviduct, with a fully formed egg in the uterus. (*R. E. Phillips.*)

kidney and is attached to the dorsal wall of the body cavity. In an inactive condition the ovary appears as a small, whitish mass of irregular contour, whereas in the active condition it appears as a yellowish cluster of spheres of varying sizes. Each sphere is enclosed in a follicle. These spheres are ova, or reproductive cells of the female, and are commonly referred to as "yolks." Each yolk contains a germinal disc, from which the embryo develops. In a hen in laying condition, as many as 3,600 ova have been counted. Many of them are so small that they can scarcely be seen with the naked eye, and others vary in size up to that of the yolk in a fully formed egg.

Experimental work has shown that if a part of the ovary is removed by operation, regeneration takes place quickly so that the ovary soon resumes its original size. Such treatment of the ovary has no effect on subsequent egg production.

The oviduct is a large coiled tube occupying a large part of the left half of the abdominal cavity in the laying hen and is suspended from the

dorsal body wall. At the anterior end of the oviduct is its mouth which is spread out beneath the ovary to receive the ova or yolks when they are ready to leave the ovary. The posterior end of the oviduct connects with the cloaca, from which the completed egg is expelled.

The oviduct consists of the following six parts: (1) the mouth, (2) the funnel or infundibulum, (3) the magnum, (4) the isthmus, (5) the uterus, and (6) the vagina, which leads to the cloaca.

THE FORMATION AND STRUCTURE OF THE EGG

All life in the higher organisms is perpetuated through the egg. The development of the embryos of mammals takes place within the body of the female, whereas the development of the chicken embryo takes place, for the most part, outside the female body. It is for this reason that the chicken yolk is such a large reproductive cell as compared with the reproductive cell or egg of a mammal. In the case of the mammalian embryo, its nourishment is obtained directly from its mother. In the case of the chicken embryo, its nourishment is obtained from the different parts of the egg, but the egg is, nevertheless, a reproductive cell. The yolk material, the albumen or white of the egg, and the shell provide nourishment for the developing embryo. The shell of the egg provides protection.

The Formation of the Yolk. In the ovary of a hen in laying condition, the ova or yolks increase in size in sequence by the accumulation of yolk material. The reason for the increase in size of the yolks in sequence is readily understood when it is recalled that hens lay in daily sequence or with one or more days alternating between layings.

It has already been pointed out that each yolk is enclosed in a follicle, which is attached to the ovary by a very slender stalk. From the inner surface of the follicle a thin membrane is secreted. This is the vitelline membrane, which contains the yolk material and the germinal disc.

Each yolk grows very slowly up to about 10 days before it is ready to leave the ovary. During the ninth and eighth days before the yolk is ready to leave the ovary, growth proceeds at a more rapid rate than previously. From about 7 to 4 days prior to the time the yolk leaves the ovary, the rate of growth is very rapid, and for the remaining 3 days the rate of growth is relatively slower. Between 7 and 6 days prior to leaving the ovary, the yolk is only about one-tenth its mature size.

During the long period of slow growth, only white yolk is added. During the rapid period of growth, concentric layers of white and yellow yolk are added when laying hens consume feed varying in xanthophyll (a carotenoid pigment) content at different periods of the day. On the other hand, when laying hens are confined and fed regularly a uniform diet, the yolk added is uniform in color. Apparently, the yolk obtains

very small amounts of carotenoid pigment from the tissues of the laying hen.

During the growth of the yolk, the germinal disc remains at the top of the yolk. Immediately beneath the germinal disc and extending into

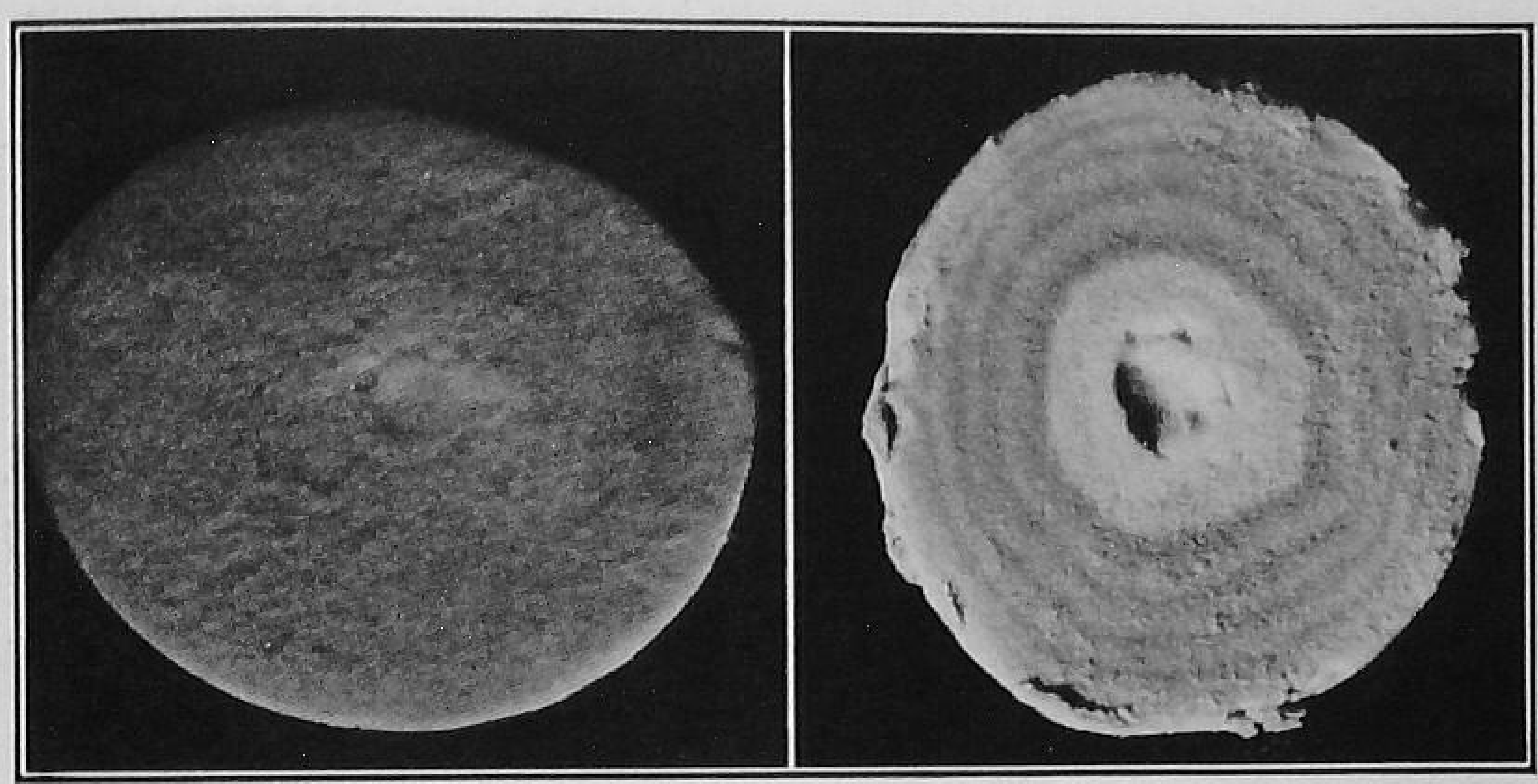

Fig. 28. Two yolks photographed in cross section. Left, a yolk produced by a hen fed a mash diet; note absence of concentric rings. Right, a yolk produced by a hen fed a diet low in xanthophyll, but yellow corn was available for 2 hr. daily. (*R. M. Conrad and D. C. Warren.*)

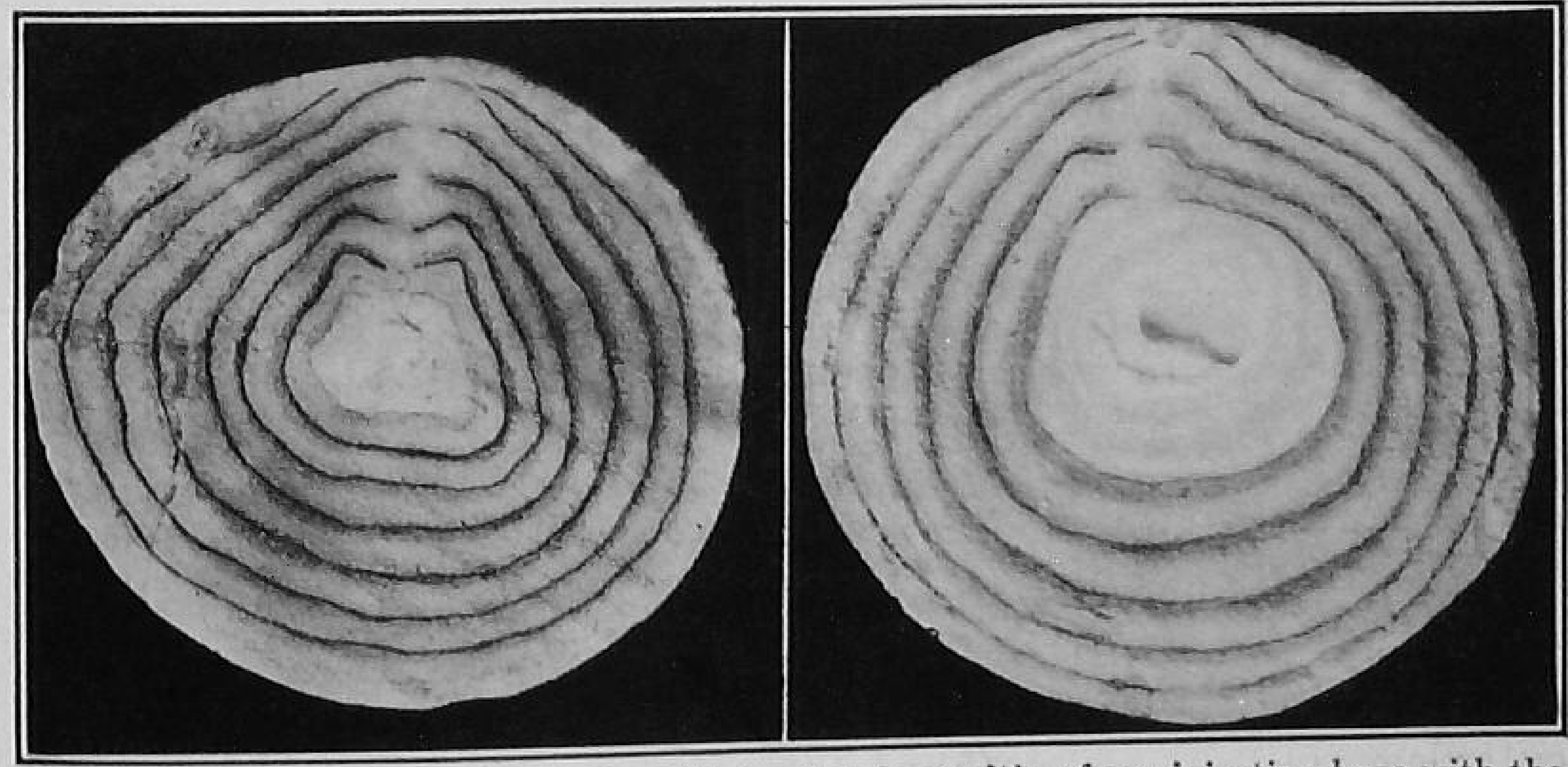

Fig. 29. Two yolks showing Sudan III dye bands resulting from injecting hens with the dye at 24-hr. intervals. Note the neck of the latebra as a break in the concentric rings. (*D. C. Warren and R. M. Conrad.*)

the center of the yolk is a flask-shaped mass of white yolk, called the "latebra." When each yolk in the ovary attains its full size, it is ready to be liberated from the ovary.

Ovulation. The release of the yolk from the ovary is brought about by the bursting of the follicle along the stigma, which is a thin area on

one side of the follicle. Ovulation, then, consists of the release of the yolk from the ovary.

Ovulation may or may not be accompanied by the grasping of the yolk by the mouth of the oviduct. If the yolk is not grasped by the oviduct at the time of ovulation, it falls into the body cavity of the hen, whence it usually is subsequently recovered by the mouth of the oviduct.

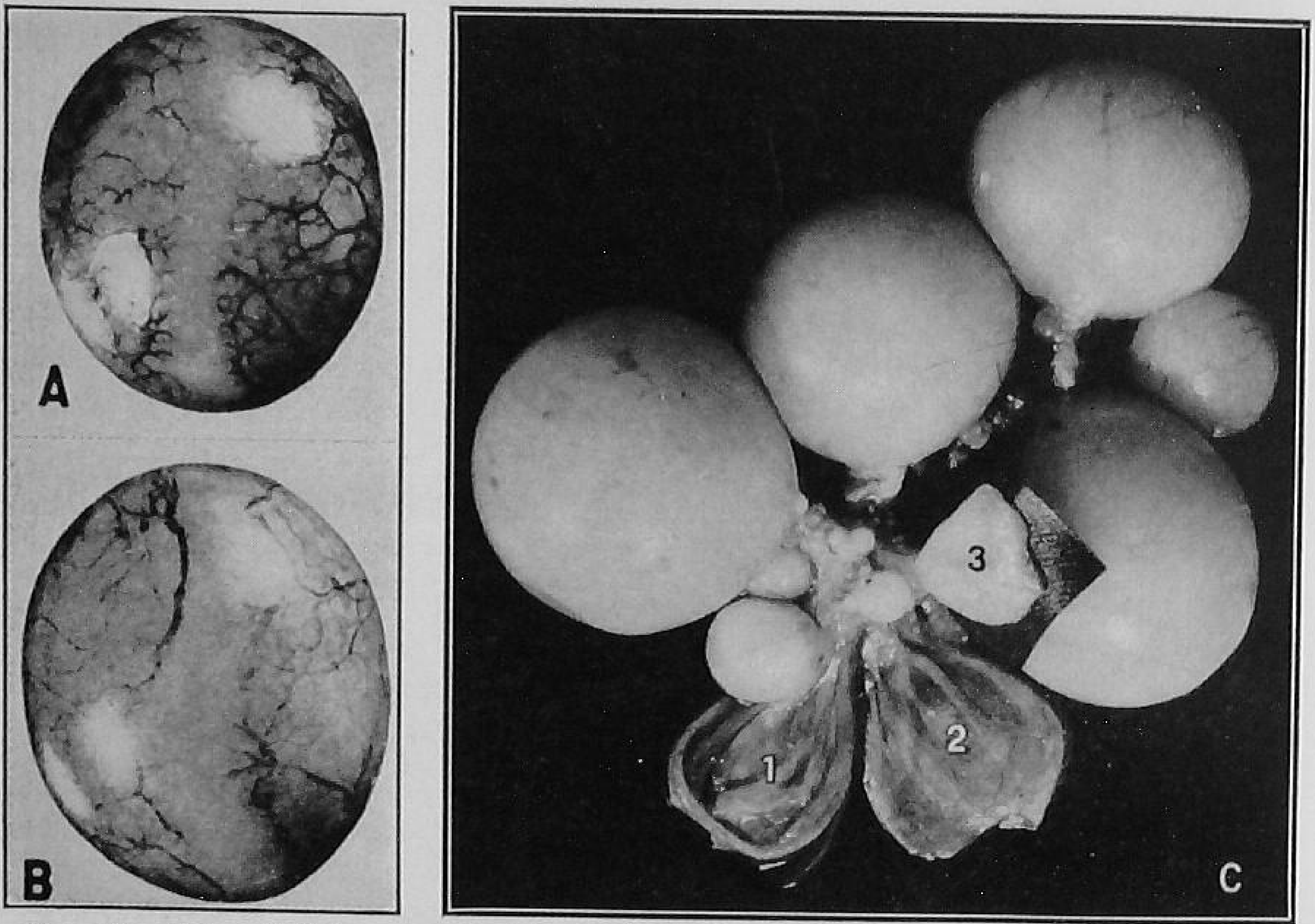

FIG. 30. (*A*) a follicle approximately 26 hr. before follicular rupture is to occur. The stigma is relatively narrow, and the blood vessels in the follicle are prominent. (*B*) a follicle immediately before rupturing; the stigma is wide and the blood vessels are less distinct. (*R. E. Phillips and D. C. Warren.*) (*C*) an ovary 3 hr. after the release of a yolk from follicles 1 and 2 (simultaneous ovulation of two yolks, resulting in the laying of a double-yolked egg). Follicle 3 ovulated its yolk the previous day. The other follicles in the ovary are in different stages of development. (*R. M. Conrad and D. C. Warren.*)

The parts of the egg that are formed in the oviduct include: (1) a layer of thick white, (2) the chalazas, (3) an inner layer of thin white, (4) an outer layer of thick white, (5) an outer layer of thin white, (6) two shell membranes, and (7) the shell. The white of the egg is also known as "albumen."

The Secretion of Thick White. Immediately upon being grasped by the mouth of the oviduct, the yolk is forced through the oviduct by ciliary action or by peristaltic movements of the walls of the oviduct. The inner surface of the magnum section of the oviduct is lined with goblet cells that secrete albumen that is relatively rich in a protein pos-

sessing the properties of a mucin. Hens that lay eggs containing a relatively high percentage of thick white have more goblet cells, especially large ones, than hens that lay eggs containing a low percentage of thick white. The thick white constitutes about 50 to 60 per cent of the total white in an egg. The thick-white percentage of total white tends to decrease from about April to July in most flocks.

The Secretion of Shell Membranes. Glands in the isthmus section of the oviduct secrete material out of which the shell membranes are formed. There are two shell membranes, an inner and an outer one. They lie immediately inside of the shell of the egg and adhere closely to each other, except usually at the large end of the completed egg, where they are separated to form the air cell. The shell membranes are composed of protein fibers and are porous. The shape of the egg is determined while it is in the isthmus.

The Formation of the Chalazas. The two chalazas in each egg are dense, cordlike structures twisted in opposite directions and extending from the yolk toward the ends of the egg. The chalazas are formed from a suspension of mucin fibers by the rotation of the yolk in the upper part of the oviduct and in the uterus. A chalaziferous or inner layer of thick white surrounds the yolk.

The Secretion of Thin White. The inner layer of thin white, between the inner and outer layers of thick white, becomes apparent while the egg is in the uterus as a result of the albumen rotating around the yolk. During the formation of the outer layer of thin white in the uterus, the principal additions to the egg are water and a mineral solution consisting largely of sodium, calcium, and potassium. The inner and outer layers of thin white each comprise about 20 to 25 per cent of the total white.

The Secretion of the Shell. The egg remains in the uterus about 20 hr. In addition to the formation of the inner and outer layers of thin white while the egg is in the uterus, the glands on the inner surface of the uterus secrete material for the shell, consisting largely of calcium carbonate. The shell is quite porous, the number of visible pores increasing greatly when eggs are held at high temperatures.

The calcium carbonate is carried to the glands of the uterus by the blood circulation. It is interesting to observe that the blood and blood plasma of birds in laying condition contain about twice as much calcium as that of birds not in laying condition. It is also interesting to note that high temperatures tend to reduce shell thickness and that the calcium content of the blood is reduced in about the same proportion.

On the outside of the shell a mucus is deposited. Shortly after the egg is laid, the mucus dries, leaving a residue called the "cuticle."

The completed egg passes from the uterus to the vagina where it is held for a short time before entering the cloaca, whence it is expelled.

In the great majority of cases eggs are laid small end first. Of the relatively few that are laid large end first, most of them become turned end for end in the uterus, apparently because the small end projects deeply into the blind sac of the uterus.

The Time Factor in White and Shell Secretion. From the time the yolk enters the mouth of the oviduct to the time the egg is laid requires about 25 hr., on the average. The approximate length of time that the yolk spends in different sections of the oviduct is shown in Table 8.

TABLE 8. APPROXIMATE LENGTH OF DIFFERENT SECTIONS OF THE OVIDUCT, APPROXIMATE PER CENT OF ALBUMEN SECRETED IN EACH OF THREE SECTIONS, AND APPROXIMATE TIME SPENT BY YOLK IN DIFFERENT SECTIONS
(Compiled from Data of Warren and Scott, 1935, and Asmundson and Burmester, 1936)

Section of oviduct	Approximate length		Approximate per cent of albumen secreted	Approximate time spent by yolk
	Centimeters	Inches		
Mouth	2.0	0.8		
Funnel	4.0	1.6	......	15 min.
Magnum	33.0	13.0	40 to 50	2 hr. 45 min.
Isthmus	10.0	3.9	10	1 hr. 15 min.
Uterus	12.0	4.7	40 to 50	20 hr. 45 min.
Vagina	5.0	1.9		

It will be seen from the data in the last column of Table 8 that the yolk spends approximately 25 hr. in the oviduct. The actual time varies somewhat among different hens, depending upon differences in rate of laying. In this connection, the time the egg spends in the uterus is important for several reasons.

The Time Factor in Laying Sequence. Some hens lay in daily sequence for several or many days before missing a day, whereas other hens lay an egg every other day or perhaps two eggs in daily sequence and then miss one day or more. The number of eggs laid on consecutive days is called a "clutch." One of the longest clutches on record is that of a White Leghorn which laid 223 eggs consecutively in an officially conducted Canadian egg-laying contest.

Among hens laying a few eggs in a clutch, ovulation usually takes place about 30 min. after the laying of the previous egg. The act of laying is

referred to as "oviposition." Since the yolk usually spends about 25 hr. or more from ovulation time to oviposition time and since the ovulation of the succeeding yolk occurs about 30 min. after the oviposition of the previous egg, the total time elapsing between two successive ovipositions, or eggs laid in daily sequence, is about 25.5 hr. or more. The actual time that elapses between layings varies, however, depending among other things upon the number of eggs laid per clutch. The

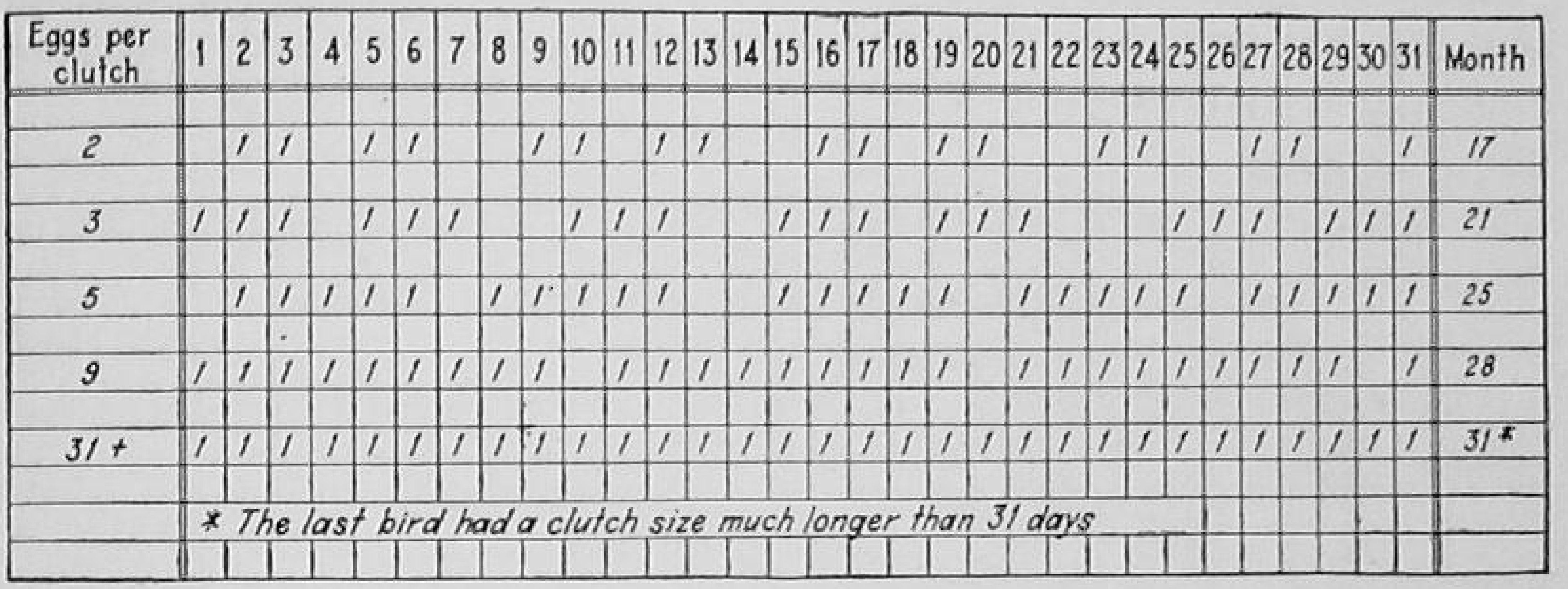

FIG. 31. Number of eggs laid in 1 month according to the number of eggs per clutch. Birds that lay 300 or more eggs in a year obviously lay in long clutches, with little more than 24 hr. between successive eggs in each clutch.

average number of hours between layings according to number of eggs per clutch in White Leghorns is as follows:[1]

Number of eggs per clutch..........	2	3	4	5	10	20	40
Average hours between layings.......	28.0	27.0	26.0	25.5	24.8	24.5	24.1

Because of the lapse of time between successive eggs in a clutch, laying generally occurs a little later each day until about 2 P.M. is reached and then a day's interval usually intervenes before the next egg is laid. Most eggs in a flock are laid between 8 A.M. and 2 P.M.

One day's interval between clutches is due to a postponement of ovulation. The laying of the first egg of the succeeding clutch is usually delayed from about 15 to 20 hr.

The Structure of the Egg. The preceding discussion on the development of the yolk in the ovary and the secretion of the different parts in the oviduct indicates the complex structure of the completed egg. It consists of five main parts: (1) the germinal disc, (2) the yolk, (3) the white, (4) the shell membranes, and (5) the shell.

The germinal disc is located at the top of the yolk beneath the vitelline membrane. When an egg is broken out into a glass dish or saucer, the germinal disc can be seen with the naked eye as a small whitish circle.

[1] From Heywang, 1938.

If it does not appear on the upper surface of the yolk in its resting position, gently turning the yolk over with the fingers will usually reveal the little circle. The germinal disc in a fertile egg gives rise to the blastoderm, and when the egg is incubated, the blastoderm gives rise to the embryo.

The yolk is comprised of a mass of yolk granules enclosed in the vitelline membrane. The yolk has a specific gravity of 1.0293.

The white is comprised of four layers, (1) an inner layer of thick white, including the chalazas; (2) an inner layer of thin white, (3) an outer layer

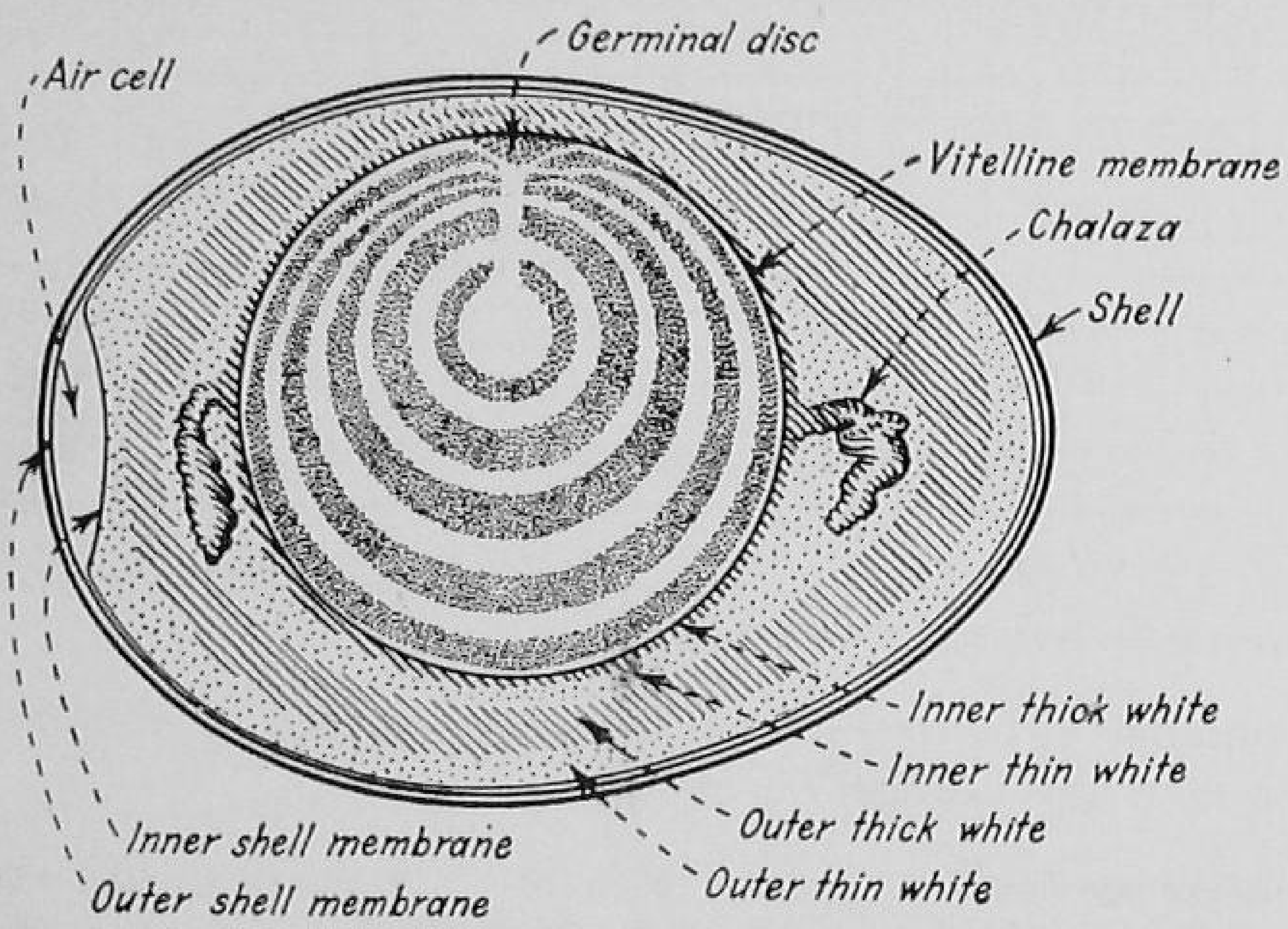

Fig. 32. Schematic representation of the structure of a hen's egg. All the principal parts are named except the bloom, or cuticle, on the outside of the shell and the concentric layers of white and yellow yolk forming the yolk. The flask-shaped structure approximately in the center of the yolk is the latebra and is comprised of white yolk. The germinal disc, at the top of the neck of the latebra, in a fertile incubated egg develops into the blastoderm, which in turn becomes the embryo. (*Modified from Schaible, Davidson, and Moore, and Adamstone.*)

of thick white, and (4) an outer layer of thin white. Immediately surrounding the vitelline membrane of the yolk is a narrow layer of thick white which extends at each end of the egg into a dense twisted cordlike structure called the "chalaza." The chalazas are of vital importance from the standpoint of ensuring a relatively uniform temperature for the developing embryo during incubation. Surrounding the inner layer of thick white and the chalazas is the inner layer of thin white. Then comes the outer layer of thick white, followed by the outer layer of thin white. The specific gravity of the white of an egg is 1.04028.

The inner and outer shell membranes are porous and adhere closely to each other immediately inside the shell, except at the large end of the egg, or occasionally at some other place, to form the air cell.

The shell is quite porous and is comprised of an inner layer of calcite crystals and a chalky layer that comprises about two-thirds of the entire shell. The porous nature of the shell and shell membranes permits the embryo to respire by the diffusion of carbon dioxide out and oxygen in. The shell serves as a protection against damage to the white and yolk and to the embryo during the incubation period. The shell is a source of calcium for the developing embryo; the dry matter of the shell consists of approximately 94 per cent calcium carbonate, 1 per cent magnesium carbonate, 1 per cent calcium phosphate, and about 4 per cent organic material, chiefly protein.

The shell of the first egg of a clutch is usually smoother than the shells of the other eggs of the same clutch. In 3-egg and 4-egg clutches, the shells of the first and last eggs are usually thicker than the shells of intervening eggs; and in clutches of many eggs, the shell of the last egg in the clutch is nearly always thicker than that of all eggs between the first and last. Aside from this, in practically all flocks, shell thickness of all eggs tends to decrease during hot weather.

Shell Color. The Mediterranean, such as Leghorns, and certain other breeds lay white-shelled eggs. In some strains of these breeds a certain proportion of the eggs may be tinted, especially in the case of the first few eggs laid by pullets. The American and many other breeds lay brown-shelled eggs. In most flocks of these breeds there is considerable variation in the shades of brown. The brown color is due to the deposition of pigment from the glands of the uterus during the entire period of shell formation, although about 50 to 75 per cent of the pigment is deposited during the last 5 hr. before oviposition occurs. The degree of pigmentation tends to decrease as egg production continues.

Egg Shape. Each hen lays an egg of a particular shape even though the size of her eggs may vary considerably. Among all the hens in a flock, there is usually considerable variation in the shape of the eggs they lay. The general shape of the egg appears to be determined largely by the amount of white secreted in the magnum section of the oviduct and by the relative size of magnum and isthmus, the latter exercising the greatest influence in determining the ultimate shape the egg attains.

Experimental operations involving the removal of a part of the albumen-secreting portion of the oviduct resulted in a considerable decrease in the amount of albumen or thick white secreted. When part of the isthmus was removed, the eggs subsequently laid were of abnormal shape and the percentage of shell was decreased. When part of the wall of the uterus was removed, the eggs laid after the operation were variable in shape and the shells weighed less than in eggs laid by the same hens before

being operated upon. The uterus, therefore, apparently exercises some influence in determining the shape of eggs.

Abnormal Eggs. The number of eggs of abnormal shape or size or that have some other peculiar feature is very small. Sometimes the oviduct secretes white, shell membranes, and shell in the absence of a yolk, the exact cause being unknown. Double-yolked eggs may result from some delay in the secretion of the shell membranes and shell before the next ovulated yolk catches up with the first one, or two yolks may be ovulated at about the same time. An egg within an egg is apparently due to a fully formed egg passing back up the oviduct and, being met by a recently ovulated yolk, the different parts of the white of the second egg are secreted and are enclosed in shell membranes and a shell along with the fully formed egg.

Rare cases have been reported of eggs being laid with an attached follicle containing a yolk and one case of an egg with an attached portion of the ovary.

Egg Size. The size of an egg obviously is determined by the collective weights of its component parts. From observations on eggs laid by different flocks, it has been found that the white contributes approximately 58 per cent, the yolk approximately 31 per cent, and the shell approximately 11 per cent of the total egg weight. But the percentage weights of the different parts of the egg and the weight of the egg itself vary during the annual production record of an individual. The weight of the white and shell depends on the area of secretory surface of the part, or parts, of the oviduct in which they are formed.

The comparatively small size of eggs laid by early maturing pullets is due, to some extent at least, to the relatively small yolk. As a matter of fact, two factors of major importance in determining the size of egg laid by birds of all ages are the size of the yolk that is formed and the size of the oviduct of the bird. Egg size is also affected by the position of the egg in a clutch, each succeeding egg in the clutch usually showing a progressive decrease in weight.

Blood Clots in Eggs. In the normal course of the formation of a certain proportion of the eggs laid by almost any flock, blood clots are found to be present either when the eggs are candled or when the contents are broken out of the shell. For the most part, these blood clots originate between the inner wall of the follicle and the vitelline membrane surrounding the yolk. In most flocks blood clots are most numerous at the beginning of the laying year; but there is often great variation among individuals in a flock with respect to the proportion of eggs containing blood clots, and strains and breeds have also been shown to vary considerably. Breeding and marketing problems involved in the production

of blood clots are discussed in subsequent chapters. Some of the so-called "meat" spots apparently may be the result of small pieces of tissue having been torn from the follicle by the mouth of the oviduct at the time of ovulation.

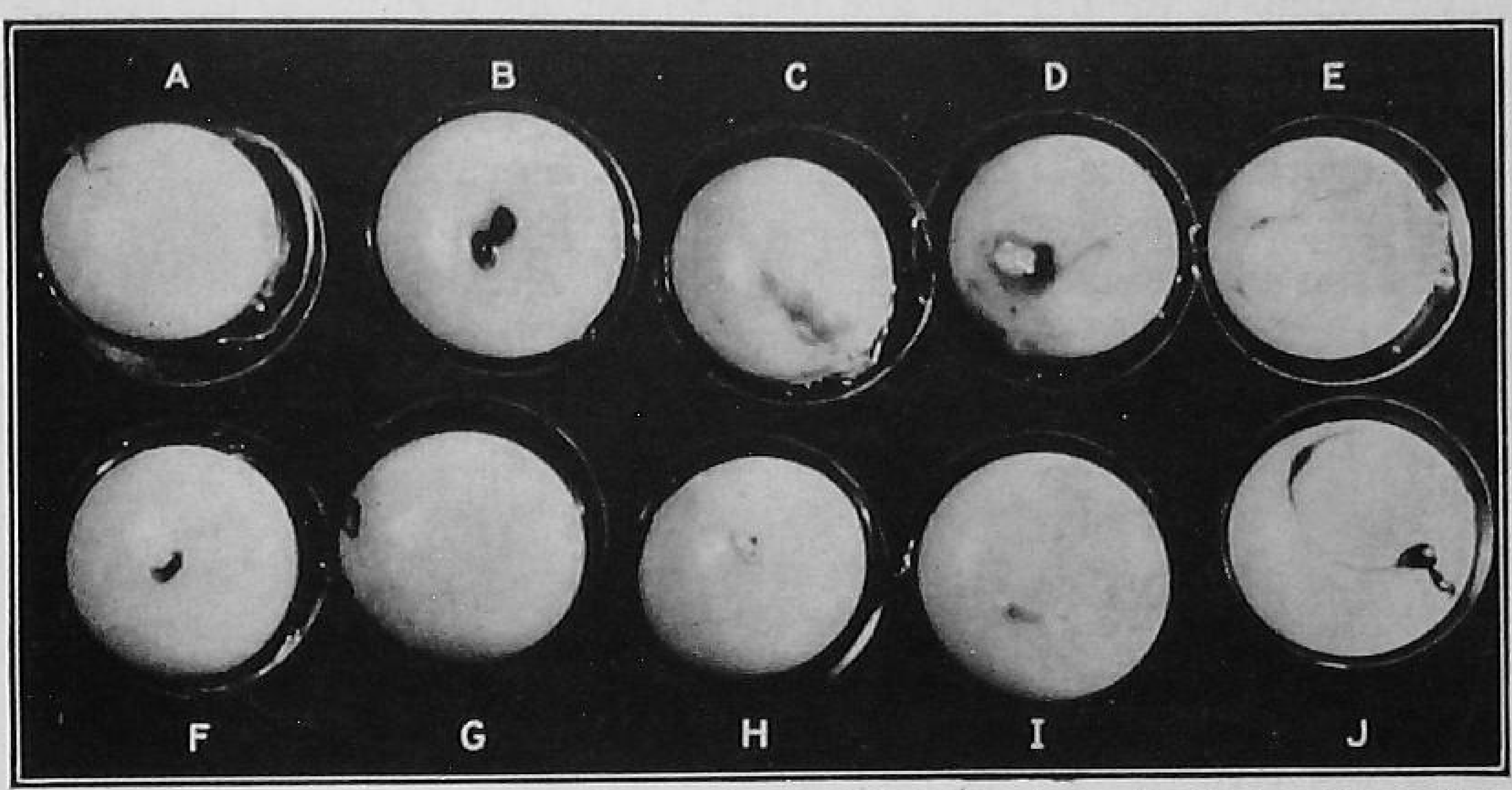

FIG. 33. Types of blood clots and spots in eggs. (*A*) blood streak; (*B*) two blood clots not attached to the yolk; (*C*) blood sheet; (*D*) combination of blood clot, blood sheet, and blood streak; (*E*) blood streak; (*F*) red blood spot; (*G*) brown blood clot; (*H*) pinkish-tan "meat" spot; (*I*) "meat" spot with dark center and white rim; (*J*) blood clot and blood streak. (*A. V. Nalbandov and L. E. Card*, 1944.)

THE ENDOCRINE REGULATORY SYSTEM

Several of the previously described processes involved in egg production are influenced in a very striking way by substances elaborated by glands or tissues located in various parts of the bird's body. These glands, the endocrine glands, secrete their specific products directly into the blood stream and are accordingly known as "ductless glands," and also as "glands of internal secretion." The secretions from such glands are called "hormones," (from the Greek *hormao*, to stir up or stimulate). Upon being secreted into the blood stream, they bring about their effects in tissues or organs remote from the site of production. It may also be added that although hormones are usually secreted in minute quantities, their effects are often quite extensive and pronounced.

The hormones secreted by the endocrine glands control the functioning of the ovary, oviduct, testes, and other organs, and influence also the development of the comb, spurs, broodiness, molting, rate of body growth, feather growth and pigmentation, and other characters.

The more important endocrine glands, their location in the body, the hormones secreted by each, and the functions of these hormones are given briefly below.

Gonad Secretions. The ovary secretes estrogens and progesterone. The estrogens influence the development of such secondary sexual characteristics as hackle and sickle feathers and the pigmentation of the feathers. In the reproductive cycle, estrogens are necessary for the development of the oviduct, and perhaps in some degree, for the regulation of anterior pituitary function. A considerable body of evidence suggests that another hormone, progesterone, must be secreted in the bird's ovary. There is some evidence that the ovaries also secrete male hormones, or androgens, with effects secondary to those of the estrogens.

The testes secrete androgens. The most obvious secondary sexual characteristic controlled by the androgens is the comb of the cock. The comb test, used with chicks or capons, has long been the standard of

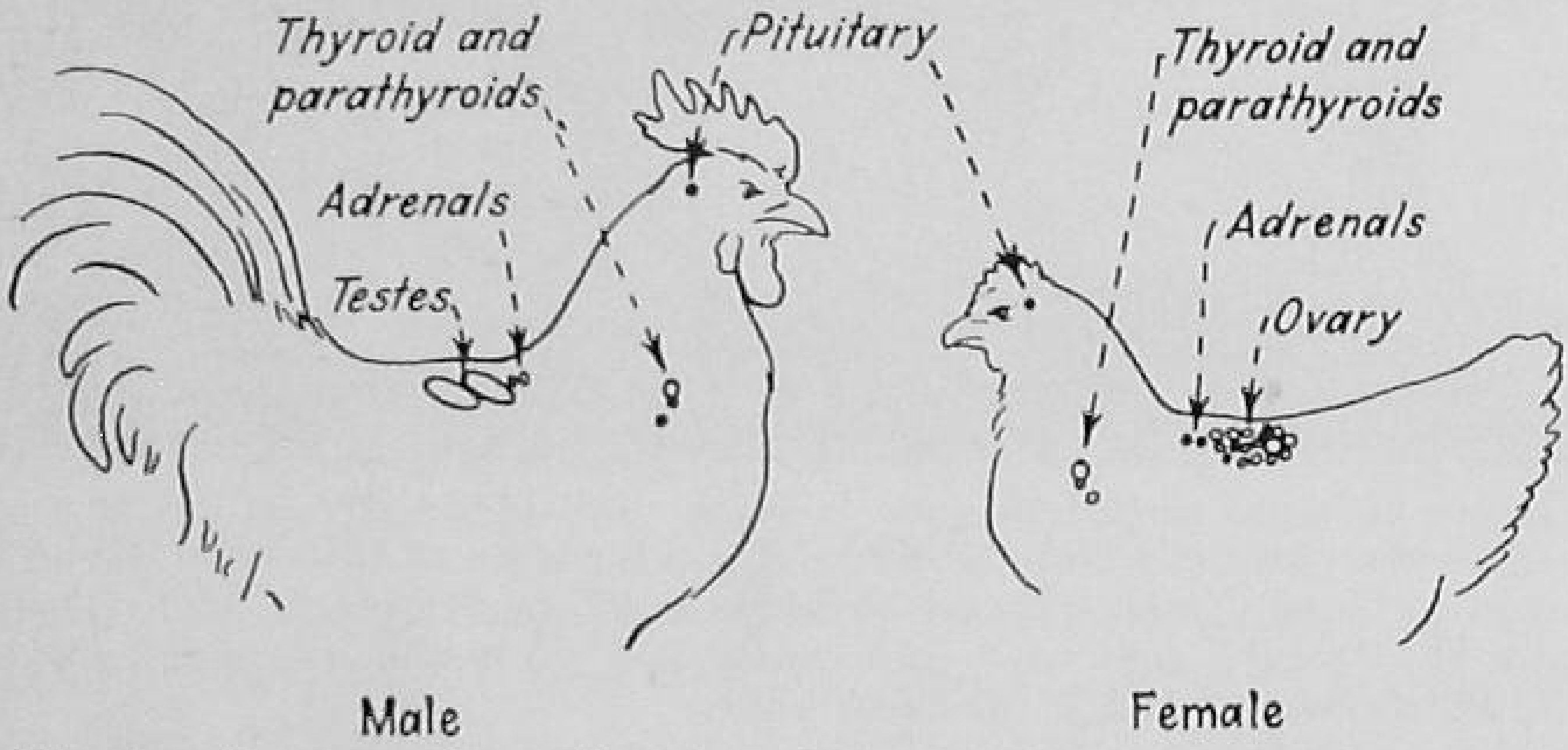

FIG. 34. Showing the approximate location of the more important endocrine glands of the male and female chicken. The thyroid is larger than either of the two parathyroids. Not shown are the pineal, thymus, and the islands of Langerhans.

biological assay for androgens. The androgens are also essential to sperm production and normal male reproductive behavior.

Thyroid Secretes Thyroxine. The thyroids are paired glands, located on the anterior faces of the cervical region, just anterior to the jugular vein. The thyroid secretes thyroxine, a hormone having primarily a pronounced effect on metabolism in the bird and secondarily on growth and many related processes. The thyroid glands depend upon a hormone secreted by the anterior pituitary for their normal function (see below).

Parathyroid Secretion. The parathyroids are located near the thyroids, whence the name. The hormone produced by these glands increases the calcium content of the blood and thus may be of importance in shell formation.

Adrenal Secretions. The adrenals are paired glands, each being about the size of a pea located at the anterior border of the kidney. The adrenals secrete two types of hormone, adrenalin and cortical hormones. Adrenalin has marked vasoconstrictor properties and is commonly used as an extract to raise blood pressure and as a heart stimulant. There are

probably several cortical hormones. They facilitate the conversion of non sugars (mainly proteins) into carbohydrates, replenishing the glycogen reserve of the body and serve in maintaining a proper mineral balance in the body. The cortical hormones are also of importance in maintaining the body's resistance to shock; for example, to low temperatures. The normal functioning of the adrenal gland is controlled by the anterior pituitary.

Insulin Secreted in Pancreas. Certain tissues in the pancreas, the "islands of Langerhans," secrete a hormone, insulin, which influences or regulates carbohydrate metabolism. While the endocrine function of the

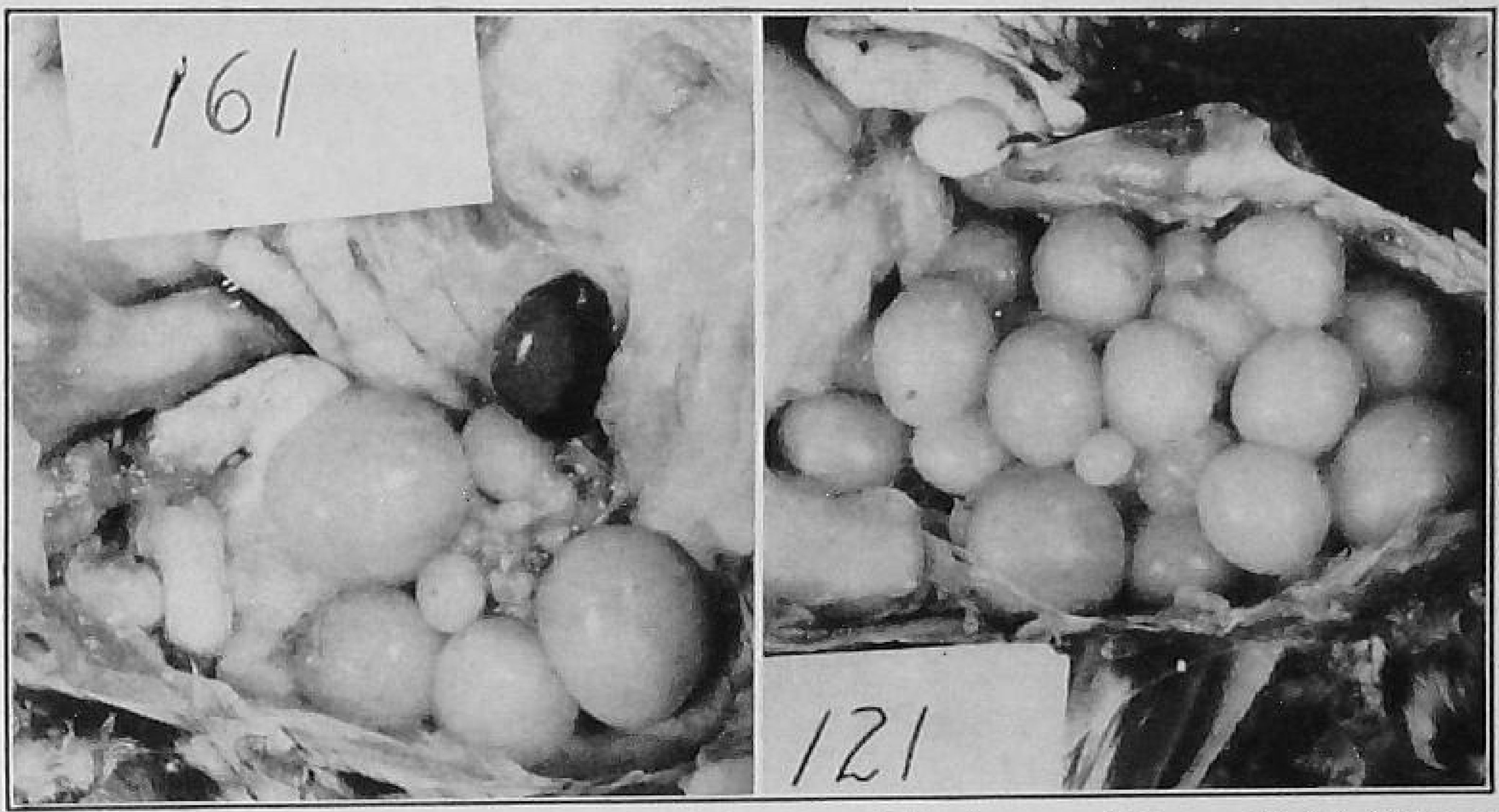

FIG. 35. Left (161), the ovary of a bird in normal laying condition. Right (121), the ovary of a bird that had been injected intramuscularly for 6 days with 0.5 m. of gonadotropic or gonad-stimulating hormone. (*R. E. Phillips*, 1943.)

pancreatic secretion is obviously of great importance, it will not be dealt with further here.

Pituitary-gland Secretions. The pituitary gland, sometimes called the "master" gland of the endocrine regulatory system, is located beneath the floor of the brain, to which it is connected by a stalk. It consists principally of three secretory parts, an anterior lobe, a closely applied posterior lobe, and an intermediate lobe. The entire gland in an adult hen is about the size of a grain of wheat.

The anterior lobe secretes at least six recognized hormones, three of which have specific effects on the gonads:

1. The follicle-stimulating hormone (FSH) in the female stimulates the growth (but not ovulation) of ovarian follicles and transforms the ovary from its quiescent condition to that characteristic of the normally laying hen (Fig. 35). The same hormone brings about testicular growth in the male.

2. The luteinizing hormone (LH) or interstitial-cell-stimulating hormone (ICSH), causes interstitial-cell stimulation and is apparently the hormone causing ovulation in the hen. Also, it probably participates in bringing about formation of those cells which produce progesterone.

TABLE 9. ENDOCRINE-GLAND HORMONES AND THEIR PRINCIPAL FUNCTIONS

Endocrine glands	Hormones secreted	Principal functions of hormones
Testis	Androgens	Influence development of secondary sexual characters and are essential to sperm production and normal male reproductive behavior
Ovary	Estrogens	Influence development of secondary sexual characters and the pigmentation of feathers. Necessary for the development of the oviduct
	Progesterone	Apparently cooperates with estrogens in regulating the oviduct
	Androgens	
Anterior lobe of pituitary	Follicle-stimulating	Stimulates growth of ovarian follicles
	Luteinizing	Causes ovulation
	Luteotrophic (prolactin)	Induces broodiness
	Thyrotrophic	Stimulates the thyroid gland
	Adrenotrophic	Stimulates the adrenal gland
	Growth-promoting	Stimulates body growth
Posterior lobe of pituitary	Oxytocin (pitocin)	Regulates oviposition
	Vasopressin (pitressin)	Constricts blood vessels
Thyroid	Thyroxine	Accelerates metabolism
Parathyroid	Parathyroid hormone	Increases calcium content of blood
Adrenal	Adrenalin	Has marked vasoconstrictor properties
	Cortin	Facilitates conversion of proteins into carbohydrates
Islands of Langerhans	Insulin	Regulates storage of carbohydrates

3. The luteotrophic hormone (LTH), prolactin, or lactogenic hormone, is possibly necessary for the maintenance of the progesterone-secreting cells in birds. The same hormone induces broodiness in hens.

The above hormones, follicle-stimulating (FSH), luteinizing (LH), and luteotrophic (LTH), are known collectively as "anterior pituitary

gonadotrophins," the ending "trophin" signifying "nourishment" of the respective gonadal functions.

In addition to the gonadotrophic hormones, the anterior pituitary gland secretes:

4. Thyrotrophin, or thyrotrophic hormone, which is required for the maintenance of normal thyroid function.

5. Adrenotrophin, or adrenotrophic hormone, which is essential for the maintenance of normal adrenal function.

6. Growth-promoting hormone, which is required for normal body growth. When secreted in excessive quantities, it leads to overgrowth of the body (pituitary gigantism).

The posterior lobe of the pituitary secretes pituitrin, which is composed of two fractions, vasopressin or pitressin and oxytocin or pitocin. Vasopressin constricts the blood vessels, and oxytocin causes the contraction of the smooth muscles of the oviduct.

At present practically nothing is known about the secretions of the intermediate lobe of the pituitary.

Pineal and Thymus Secretions. In addition to the above organs of internal secretion, endocrine functions have been attributed to certain glandlike structures, of which the pineal gland and thymus are perhaps the most often discussed. These are of little importance to the purposes of the present survey.

HORMONAL CONTROL OF OVULATION AND LAYING

There is a definite time relationship between the successive ovulations, between the lay of a given egg and of the ovulation of the succeeding ovum, and between the lay of successive eggs, as has been observed previously. The various complex relationships existing between successive ovulations, the time the egg spends in the oviduct, and the sequence of successive ovipositions are timed with remarkable precision, and perhaps this element of timing is the most distinguishing characteristic of the regulatory mechanism involved in ovulation and laying. So far as is known at present, the regulatory mechanism is almost entirely an endocrine mechanism. The endocrine control of ovulation and laying will be taken up briefly under the following headings:

1. *Follicular growth.* The anterior lobe of the pituitary secretes a hormone that stimulates the rate of growth of the ovarian follicles, the last phase of follicular growth being characterized by the growth of the follicles from a fraction of a gram to from 16 to 20 g. in a period of only about 8 days. Commercially prepared gonadotrophic extracts, primarily follicle-stimulating preparations, stimulate follicular growth, partly, however, through the interruption of ovulation and the accumulation of

nonovulated yolks on the ovary. Photographs of such FSH ovaries are shown in Fig. 35.

2. *Ovulation.* The final changes which make a follicle or yolk ovulable are little understood. The fact that some basic change must occur in the follicle within a brief time, no more than about 26 to 27 hr., is evident when one reflects that a follicle showing no response whatever to an ovulation-inducing hormone today will ovulate readily tomorrow. Ovulation is not, however, an automatic process. A specific hormone is required for its consummation, which culminates in the rupture of the stigma of the follicle and the explusion of the contained ovum.

Experimentally, ovulation can be induced much before the time of its normal occurrence by the administration of appropriate hormones. These are usually administered intravenously, although progesterone is highly effective when injected subcutaneously.

A considerable body of experimental evidence indicates that the ovulation-inducing hormone of the bird is the luteinizing hormone. This has been prepared from chicken anterior pituitary glands by the same procedure used in the fractionation of sheep anterior pituitary glands. As little as 1 gamma (0.001 mg.) will force ovulation prematurely. Luteinizing preparations of mammalian origin are also effective in inducing ovulation. Progesterone, which so easily induces ovulation in the hen, apparently does so by causing the release of the luteinizing hormone (LH) from the hen's anterior pituitary gland.

At ovulation time, the mouth of the oviduct acts under the stimulus of a hormone to receive the yolk. Apparently, the oviduct is in a receptive condition about ½ hr. before and after ovulation.

An interval of about 25.5 hr. intervenes between the ovulation of a yolk and the laying, oviposition, of the egg containing the previously ovulated yolk of that clutch. Pituitrin, a hormone secreted by the posterior pituitary, will induce premature expulsion of the egg from the uterus. The intravenous injection of commercially prepared compounds containing these posterior pituitary fractions have shown that vasopressin is relatively more effective than oxytocin in causing premature oviposition or expulsion of the egg from the uterus of the hen. The ruptured follicle from which the yolk was released also affects the time of laying of the egg containing that yolk, since the surgical removal of the ruptured follicle causes the egg to be held in the uterus for varying lengths of time up to 7 days.

Another phase of the hormone regulatory influence on egg laying involves a light-sensitive factor. The fact that laying does not usually take place after 2 P.M. and only rarely after 4 P.M. indicates that ovulation and time of laying are influenced by light acting upon the anterior

pituitary through the medium of the eye. Additional evidence indicating the influence of light on time of laying is borne out by the fact that when laying hens are kept in darkness during the normal daytime and are artificially lighted at night, most of the eggs are laid during the lighted night period. On the other hand, the results of experiments involving the shifting of feeding time and lighting period demonstrate that the time of laying is also influenced by the activity of the birds during the feeding period irrespective of the lighting periods employed. The practical application of the principle involved is discussed in another chapter under the problem of artificially lighting layers to stimulate increased egg production.

HORMONE INFLUENCE ON COMB AND GONAD DEVELOPMENT

When a male chicken has its testes removed by operation (castration), it develops into a capon and as an adult has a much smaller comb than an uncastrated male of the same age. This indicates that in males the testes influence the development of the comb.

In young males the growth of the testes proceeds at a more rapid rate than body growth. The growth of the testes affords evidence of the very early secretory activity of the anterior pituitary. In one experiment, when the anterior pituitary was removed by operation from White Leghorn males about 65 days old, the combs decreased greatly in size and became caponlike in appearance.

When the gonad-stimulating hormone is injected into normal male chicks, the combs grow larger than normal and sexual behavior develops precociously. Males crow as early as 9 days of age and tread females as early as 13 days of age. The thyroid glands become enlarged. After injections are discontinued, the combs and thyroids return to their normal size.

In Fig. 37, at the left, is shown the shrunken comb of a White Leghorn hen in August and, at the right, the comb of this hen after she had been given 51 daily injections of synthetic male sex hormone.

When the thyroids are removed by operation, the testes become greatly reduced in size and the combs grow much more slowly than in normal birds. The birds without thyroids also grow more slowly.

The removal of the adrenal glands by operation causes the degeneration of the testes, apparently through the direct influence of the anterior pituitary. The birds without adrenals look like capons.

Estrogens, female sex hormones, injected into female chicks produce an enlargement of the oviduct. In one experiment large doses of a synthetic estrogen caused the oviducts to enlarge forty-eight times that of untreated or control chicks. Estrogen injections were commenced

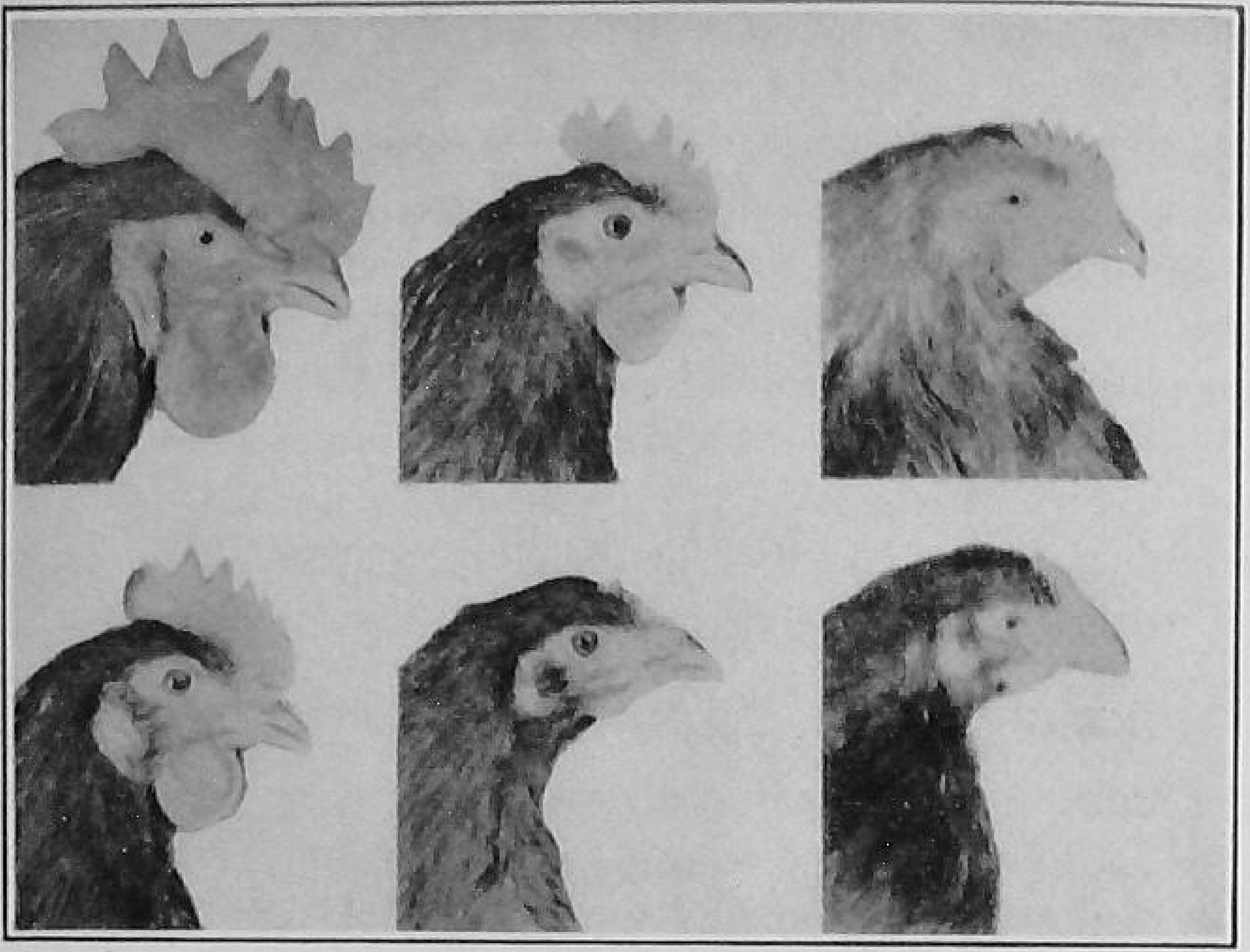

FIG. 36. Showing the effects of male and female sex hormones, respectively, on comb and wattle development in males, top row, and in females, bottom row. These New Hampshires were approximately 11 weeks of age when photographed. The center bird in each row shows normal comb and wattle development at approximately 11 weeks. The bird at the left in each row shows the effects of male sex hormone (testosterone propionate), one 10-mg. pellet having been implanted subcutaneously in the upper part of the neck at approximately 8 weeks of age. The bird at the right in each row shows the effects of female sex hormone (diethylstilbestrol), one 15-mg. pellet having been implanted subcutaneously in the upper part of the neck at approximately 8 weeks of age. (*C. S. Shaffner, University of Maryland.*)

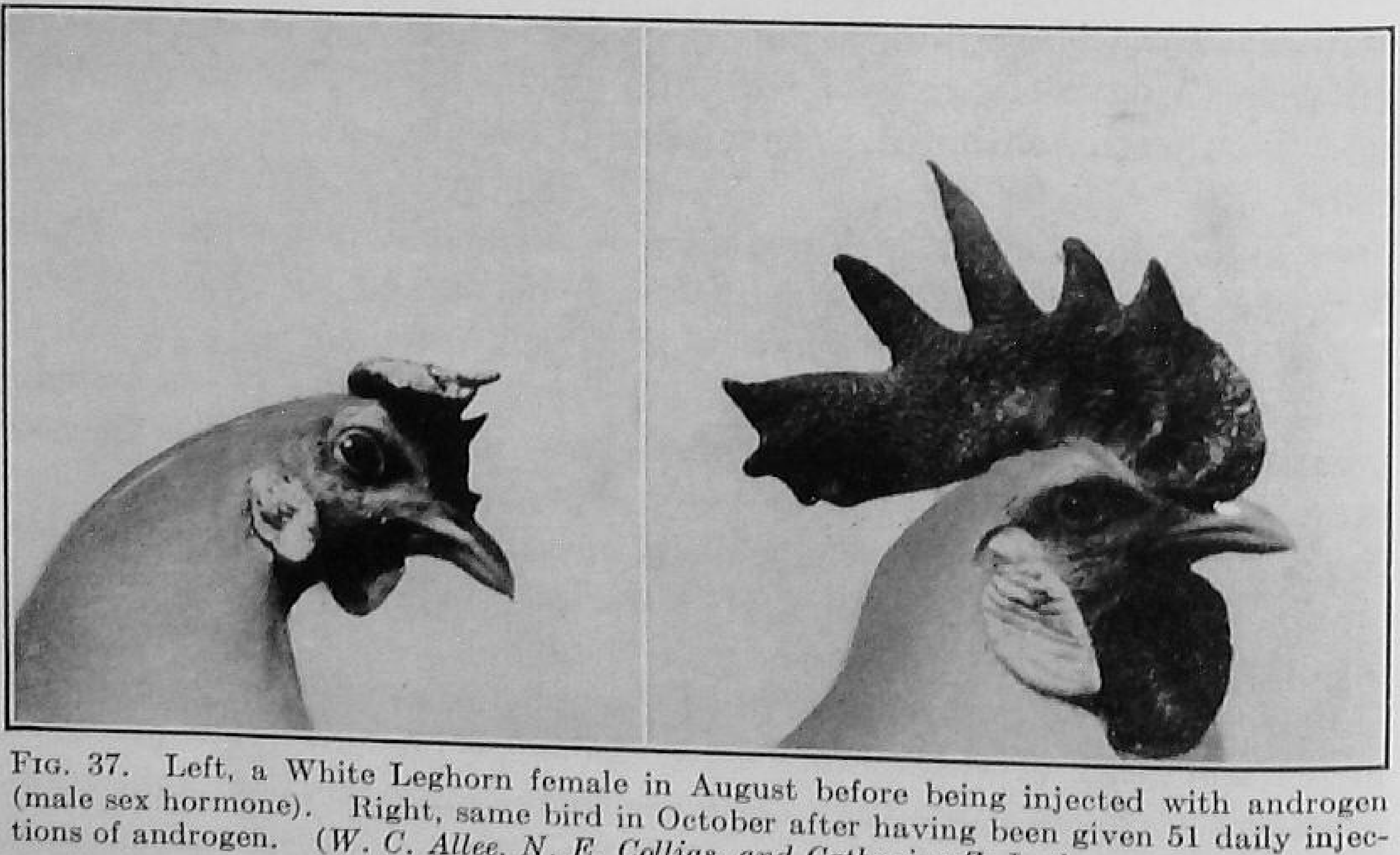

FIG. 37. Left, a White Leghorn female in August before being injected with androgen (male sex hormone). Right, same bird in October after having been given 51 daily injections of androgen. (*W. C. Allee, N. E. Collias, and Catharine Z. Lutherman.*)

when the chicks were 18 days old, and the oviducts were observed when the chicks were 40 days old. It was also found that injection of an androgen, male sex hormone, stimulated the development of the oviduct in excess of the untreated birds. The results of another experiment showed that the injection of a different estrogen into chicks 48 hr. old caused the oviduct to increase ninety times the size of the oviduct in untreated chicks. All the chicks were killed on the tenth day after the first injection.

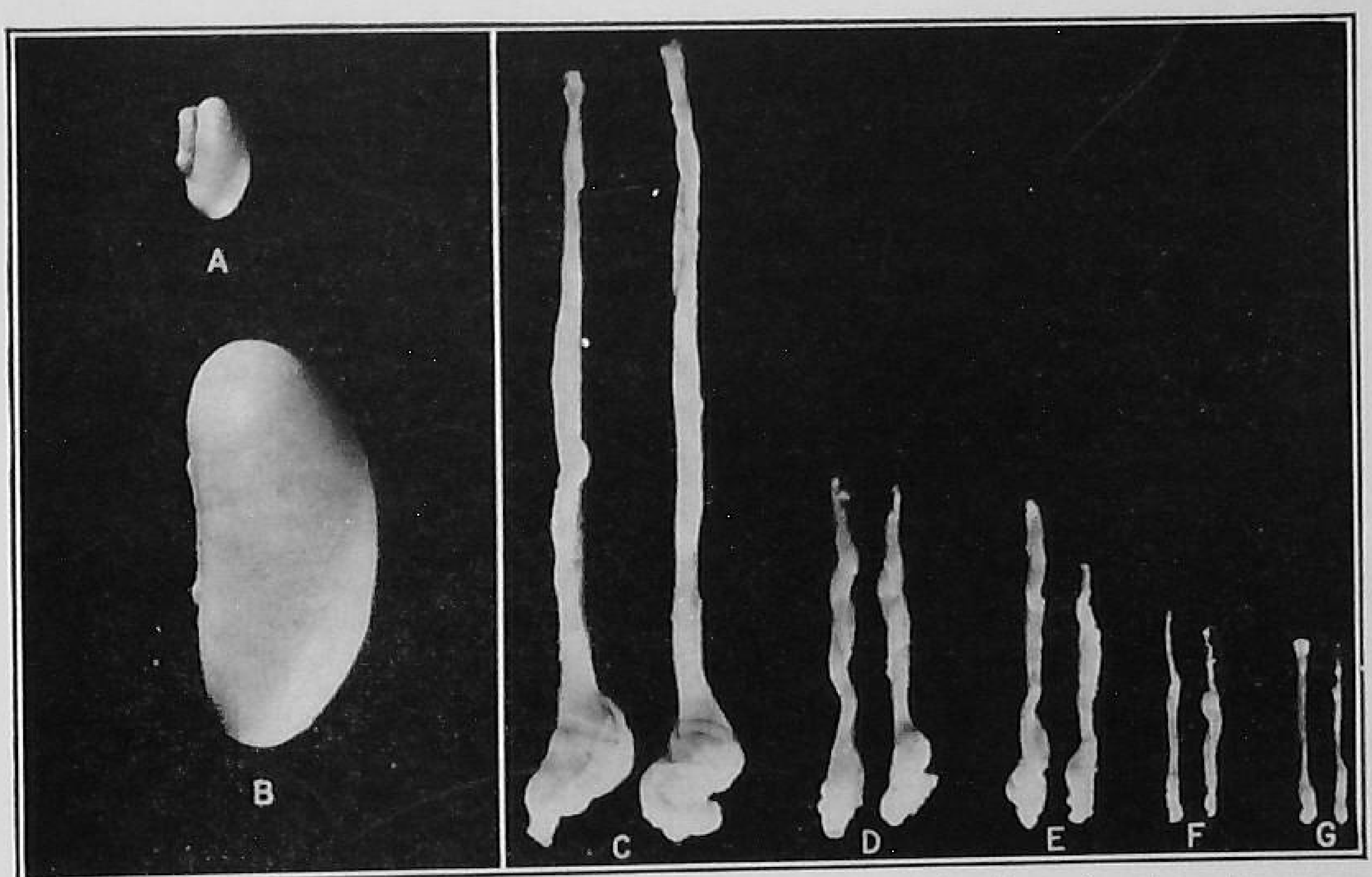

FIG. 38. Left (*A*) testis from White Leghorn given 22 daily injections of male sex hormone prior to being killed at 105 days of age. Left (*B*) testis of normal (untreated) White Leghorn at same age. Right, from left to right in pairs, an oviduct from each of two birds injected between 18 and 38 days of age with: (*C*) large doses of stilbestrol, female sex hormone; (*D*) smaller doses of stilbestrol, female sex hormone; (*E*) doses of estrone, female sex hormone; (*F*) small doses of testosterone propionate, male sex hormone; (*G*) oviducts from untreated birds of same age. (*E. H. Herrick*, 1944.)

That the oviduct is under the influence of a hormone secreted by the ovary is shown by the great reduction in size of the oviduct in birds from which the ovary is removed by operation. The secretory activity of the ovary is influenced by the gonad-stimulating hormone secreted by the anterior pituitary, as mentioned previously.

HORMONE INFLUENCE ON FEATHER STRUCTURE AND PIGMENTATION

In all breeds of the domestic fowl, except a few hen-feathered breeds mentioned in Chap. 2, the lower neck, saddle, sickle, and tail feathers are longer in the male, and the first three kinds of feathers are also more pointed in the male than in the female.

In many of the parti-colored breeds and varieties, such as the New Hampshire and Brown Leghorn, there is sexual dimorphism of plumage pattern because of the fact that the hackle and saddle feathers of the male differ in shape from the neck and back feathers of the female.

When a cock is castrated and becomes a capon, there are no changes in the male feathering with the exception that sometimes the coverts over the secondaries tend to become longer. On the other hand, when the left ovary of a hen is removed by operation, she acquires male or capon plumage. After some time, however, the rudimentary right gonad tends to enlarge, often secreting first androgens and later estrogens. These last cause the operated hen to reassume her original female plumage. In order to obtain a permanently male-feathered hen, it is therefore necessary to remove both the left ovary and the right rudiment. If testicular grafts are transplanted into such a female, she retains the male or capon type of plumage. On the other hand, when the ovary of a hen is transplanted into a cock or into a capon, its male-type plumage becomes modified to female. The results of these experiments demonstrate that the hormone secreted by the testes does not modify the male or female plumage but that the hormone secreted by the ovary suppresses the development of male plumage.

The injection of a female sex hormone into a Brown Leghorn or other parti-colored capon causes him to acquire not only female-type plumage but also the normal plumage color of the female. For instance, the black breast feathers of the Brown Leghorn capon are replaced by red- and salmon-colored feathers characteristic of the female.

That the female sex hormone secreted by the ovary is not the only factor involved in plumage type and coloration has been demonstrated by the results secured from numerous experiments. Thyroxine, the hormone secreted by the thyroid gland, exercises a pronounced effect on the structure of feathers. In a book of this kind only a few illustrations need be given.

Relatively heavy doses of desiccated thyroid fed to birds with buff plumage results in the depigmentation of the feathers. On the other hand, feeding lesser amounts of desiccated thyroid than those reported to produce depigmentation resulted in the pigmentation of the feathers of cockerels and capons but not of the feathers of hens. The response in the feather germ to thyroxine is roughly proportional to the dosage.

Thiouracil, a synthetic compound which tends to suppress the activity of the thyroid gland, when fed to birds in relatively small amounts, causes the feathers to grow longer and narrower, and barbulation is reduced. The removal of the thyroid gland by operation causes the feathers to appear lacy, due to the absence of barbules.

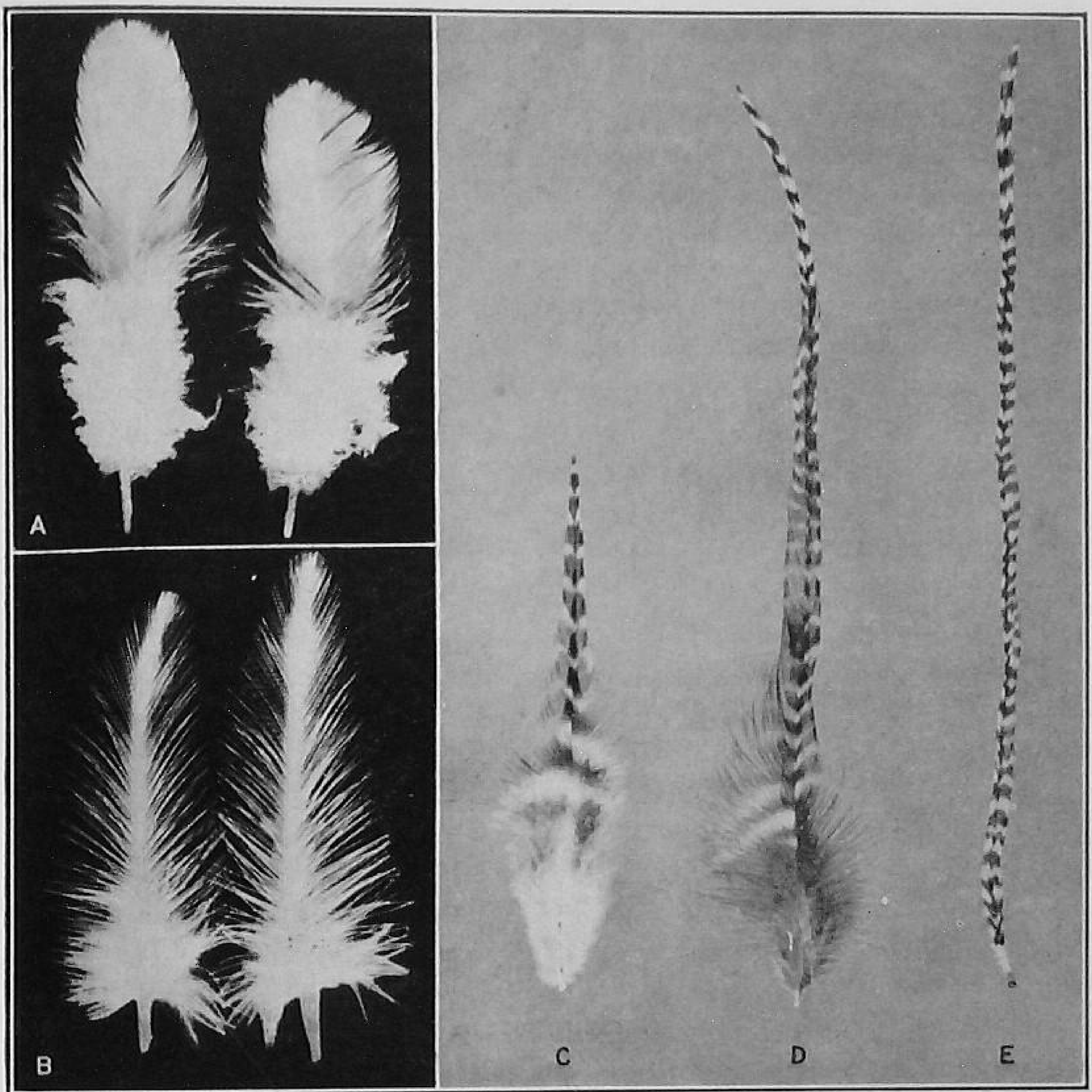

FIG. 39. Left (*A*) breast feathers of a normal White Leghorn female. (*B*) breast feathers of a White Leghorn female from which the thyroid had been removed; note lack of barbule formation. (*L. W. Taylor and B. R. Burmester*, 1940.) Right (*C*), (*D*), and (*E*) are feathers of a crossbred male secured from a mating of a Brown Leghorn sire and a Barred Plymouth Rock dam. (*C*) is a feather of normal length before the bird was fed thiouracil. (*D*) is a full-grown feather after the bird had been fed thiouracil for many months; note that the vane is narrower than in (*C*) and there is a decrease in barbulation. (*E*) is a feather that was still in a growing condition at the time of the death of the bird after it had been fed thiouracil for many months. (*Mary Juhn and M. A. Jull*, 1947.)

HORMONE INFLUENCE ON FATTENING

Cockerels normally grow at a more rapid rate than pullets, but pullets become mature relatively earlier and accumulate fat in the body at an earlier age than cockerels.

The growth-stimulating hormone and the thyroid-stimulating hormone secreted by the anterior pituitary affect rate of growth and metabolism. Thyroxine, secreted by the thyroid gland, stimulates the metabolism of

tissue cells and also inhibits the anterior pituitary with respect to its secretion of the thyroid-stimulating hormone. Thus there exists a delicate balance between the functional level of the anterior pituitary and the thyroid.

During the period of rapid growth there is little tendency for chickens to store fat in the body or in the tissues. The results of recent research have shown, however, that considerable increase in fat deposition during early growth may be secured through the feeding of synthetic estrogens or by implanting them in the form of pellets in the neck of the fowl.

The blood of females in laying condition has a much higher fat content than the blood of nonlaying females. The relatively higher fat content of females in laying condition is due to the secretion of estrogen, the female sex hormone.

Estrogens have an inhibiting effect on the anterior pituitary, resulting in a decrease in its secretion of gonad-stimulating hormones. A deficiency of these hormones leads to a decrease in the size of testes in males. The greatly reduced testes secrete less androgens, or male sex hormones, and therefore the comb shrinks, and estrogen-treated males have the appearance of capons if the treatment is continued long enough.

Since the estrogen treatment of males induces in them an increase in blood fat and since it cannot be used in the formation of yolks, its only other outlet is to the adipose tissue. Different synthetic estrogens vary in their potency. Some give better results when implanted in the form of pellets in the neck, and others give better results when fed in the fattening diet. Most of them are toxic at too high levels. In addition to the increase in fat deposit resulting from administering estrogens, the flesh of old males is sometimes made more tender.

Cockerels treated with synthetic estrogens for a sufficient length of time have greatly reduced combs and pale-colored wattles. To that extent these cockerels resemble capons, but if estrogen treatment is discontinued, the combs and wattles regain their normal size and become quite red. To speak of "hormone caponization," as is sometimes done, is quite misleading because the effects of estrogenic treatment are temporary in nature, and shortly after estrogen treatment is discontinued, the testes regain their normal size. If the cockerels are to be marketed while under estrogenic treatment, an androgen rubbed on the combs and wattles causes them to regain their bright red color and increase in size. The method of administering estrogens in fattening chickens for market is discussed in the chapter on Feeding Practice.

Since the administration of estrogens to chickens raises the question of the estrogenic potency of the tissues when the birds are slaughtered for human consumption, it has been noted that most of the exogenous

estrogen is excreted or inactivated. That which remains in the bird is contained mostly in the fat and in the liver.

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CHAPTER 4

BREEDING PRINCIPLES

The breeding worth of a male and a female is demonstrated very largely by the kind of progeny they produce. This is true regardless of the character involved. A male and a female each with a fine shape of comb may produce progeny having a poor shape of comb. A male whose dam had a high record of egg production mated to a female with a high egg record frequently produces daughters that lay poorly. The results secured from a given mating are determined largely by the genetic constitution of the birds mated rather than by their physical appearance.

Chickens are bred primarily for egg and meat production, although some poultry breeders are more interested in producing birds of a particular type or with a particular plumage pattern. Whatever may be the object, marked progress can be achieved only when the poultry breeder has an intelligent understanding of the principles involved in the inheritance of the different characters that fowls possess.

Inheritance is transmission from parent to offspring. The characters are not transmitted bodily, however, but it is the ability to develop such characters as single comb, barred plumage, and egg production that is inherited. Although it is true that the characters which a fowl possesses are not transmitted bodily, it is customary for the sake of simplicity to speak of the "inheritance of such and such a character." For instance, it is proper to speak of the inheritance of single comb, the inheritance of barring, and the inheritance of egg production.

Reproductive Cells. The transmission of characters from parent to offspring is made possible by means of a definite mechanism involving certain constituents of the reproductive cells of the male and of the female. The reproductive cells are produced by the gonads, the testes of the male and the ovary of the female. The male reproductive cells are called "spermatozoa" (singular, "spermatozoon"). The female reproductive cells are called "eggs" or "ova" (singular, "ovum").

The Significance of Mating. The act of copulation between male and female brings about the union of a spermatozoon and an ovum. At the time of copulation the male ejects semen containing spermatozoa into the cloaca of the female, the spermatozoa traverse the oviduct, and one spermatozoon fertilizes the germ spot in the ovum almost as soon as the ovum, or yolk, has been grasped by the mouth of the oviduct. The

union of the spermatozoon and ovum is necessary in order that offspring may be produced, but the really significant thing that mating accomplishes is to produce new combinations of hereditary characters, a subject discussed more fully later.

Gametes and Zygotes. From the standpoint of the inheritance of characters, the reproductive cells are spoken of as gametes, the term "gamete" meaning a spouse. The spermatozoon is the male gamete, and the ovum is the female gamete. The fertilization of the female gamete by the male gamete produces the fertilized egg, which is termed a "zygote," meaning yoked together. Thus, a male and female gamete unite to produce a zygote, which develops into the chick.

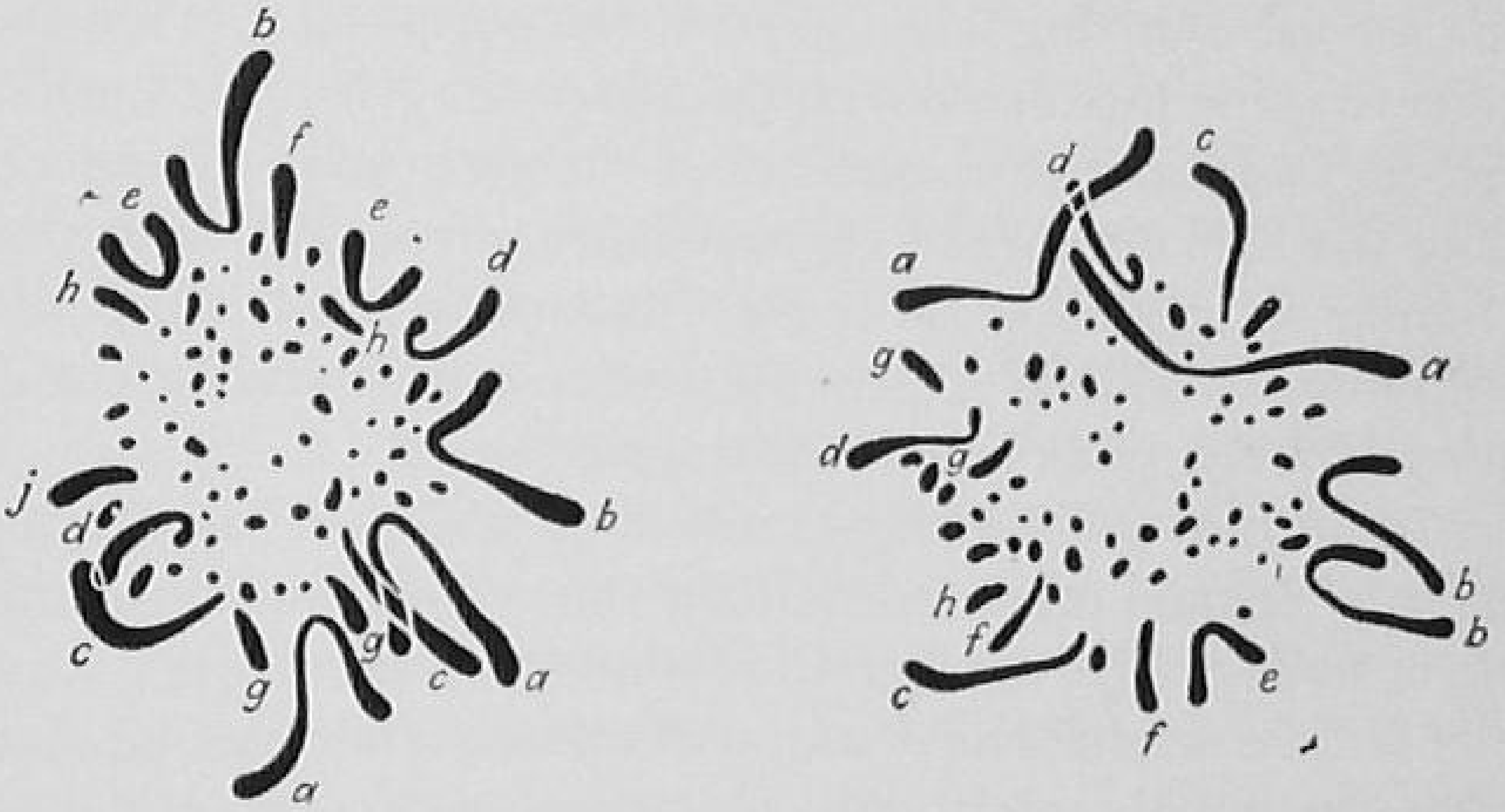


FIG. 40. Left, sketch of the chromosomes of the male fowl; the two *e* chromosomes are regarded as being the sex chromosomes. Right, chromosomes of the female fowl; note that there is only one *e* or sex chromosome. (*Y. Yamashina*, 1944.)

Chromosomes, Vehicles of Transmission. Each gamete contains little threadlike bodies called "chromosomes," which are transmitted from parent to offspring.

The male zygote in birds has one more sex chromosome than the female zygote. The sex chromosomes in any species may be a factor in sex determination, hence their name. The rest of the chromosomes are called "autosomes," and they are always in pairs in the zygote. The male chicken, therefore, has a certain number of pairs of autosomes and two sex chromosomes, whereas the female has the same number of pairs of autosomes and one sex chromosome.

Since the male has a certain number of pairs of autosomes and two sex chromosomes, it is obvious that the zygote from which he developed was produced by the union of two gametes each of which contained half the number of autosomes and one sex chromosome. Since the female has a certain number of pairs of autosomes and one sex chromosome, it is obvious that the zygote from which she developed was produced by the union of a gamete containing half the number of autosomes and one

sex chromosome and a gamete containing half the number of autosomes but no sex chromosome.

Up to the present only one phase of the reproductive cycle has been discussed, the union of a gamete of paternal origin with a gamete of maternal origin. The other phase of the reproductive cycle consists of the development of the gametes from the zygotes. For the sake of simplicity, the behavior of the sex chromosomes in the processes involved is omitted from this brief discussion. Each zygote gives rise to numerous germ cells. The chromosomes in each germ cell unite in pairs, a particular chromosome of paternal origin pairing with a similar chromosome of maternal origin. The chromosomes then split lengthwise twice. After the second splitting is completed, the germ cell divides, half of the chromosomes going into one cell and half into the other; each cell contains, therefore, half as many chromosomes as the germ cell. These cells, each containing the half number of chromosomes, are called "gametes."

The female is spoken of as being "heterogametic," since the female zygote produces two kinds of gametes with respect to the sex chromosome. The male is spoken of as being "homogametic."

A very important point always to be kept clearly in mind is that when the gamete of female origin containing the sex chromosome unites with a gamete of male origin, the zygote produced is a male, whereas when the gamete of female origin that does not contain the sex chromosome unites with a gamete of male origin, the zygote produced is a female. Another fundamental point always to be kept clearly in mind is that either of the unlike gametes of female origin may mate with either of the like male gametes.

Genes Give Rise to Characters. The chromosomes are the bearers of the determiners of hereditary characters, but since there are hundreds of characters and only a certain number of pairs of autosomes and one or two sex chromosomes, according to the sex, it is obvious that each chroomsome must contain many determiners. According to the best information available, the chicken has 38 pairs of autosomes. The male chicken has 38 pairs of autosomes and 2 sex chromosomes. The female chicken has 38 pairs of autosomes and 1 sex chromosome. The determiners of hereditary characters are called "genes," each chromosome containing many of these small units. The genes give rise to such characters as single comb, white skin, black plumage, broodiness, hatchability, and egg production.

INHERITANCE OF CHARACTERS

Much of the existing knowledge concerning the mode of inheritance of characters in poultry is due to the results which Mendel secured in

breeding edible peas. Mendel's results were published in 1866 but remained unnoticed until 1901. When the significance of Mendel's results became apparent, notable advances were made in determining the mode of inheritance of many plant and animal characters.

During recent years results have been secured which demonstrate that numerous characters of the domestic fowl are inherited in typical Mendelian manner. Most of these characters are simple ones, involving, for the most part, color and structural characters. At the same time, some progress has been made in determining the mode of inheritance of more complicated characters, such as hatchability and egg production.

Dominance and Recessiveness. Dominance exists with respect to the inheritance of many characters that are produced by the genes borne on the autosomes. For instance, when a Black Rose-comb Bantam of either sex is mated with a White Rose-comb Bantam of the opposite sex, all the offspring are black. In this particular cross the gene for black plumage is dominant to the gene for white plumage, or, more briefly, black is dominant to white. White is said to be recessive to black.

On the other hand, when a White Leghorn is mated to a Black Hamburg or any other kind of a black male, the offspring are white, or have a little black in a few of their feathers. The White Leghorn carries a gene which inhibits the development of pigment and in this respect differs from all other chickens with white plumage. When a White Leghorn of either sex is mated with a Rhode Island Red, New Hampshire, Partridge Plymouth Rock, or any other kind of a "gold" bird of the opposite sex, the progeny often have some red in the plumage, indicating that the white of the White Leghorn is not completely dominant to color (see Fig. 41).

In certain cases there is a lack of dominance of one character over the other. For instance, when two breeds differing greatly in body size are crossed, the adult progeny are usually intermediate in weight. Also, when a breed laying white-shelled eggs is crossed with a breed laying brown-shelled eggs, the female progeny lay tinted-shelled eggs.

The manner in which the characters black and white are inherited in a cross between Black Rose-comb and White Rose-comb Bantams serves to illustrate the mechanism involved in the inheritance of many pairs of characters (see Figs. 42, 43, and 44). The parental generation, meaning the parents used in the original cross, is designated by the symbol P_1. The offspring, or progeny, secured from the original cross is known as the first filial generation and is designated by the symbol F_1. When members of the first filial generation are mated among themselves, they produce the second filial generation, which is designated by the symbol F_2. Briefly, then, P_1 produces F_1, and F_1 produces F_2.

In studies on the inheritance of characters, backcross or test-cross matings are sometimes made. A backcross mating consists of mating an F_1 bird to a member of one of the parental breeds; the usual kind of backcross mating made involves a bird with the recessive character.

Homozygous and Heterozygous Individuals. The genes for black in the Black Rose-comb Bantam are in pairs, one of each pair being borne in one of a pair of autosomes. Likewise, the genes for white in the White Rose-comb Bantam are borne in the autosomes, and the genes are in pairs. Since the black parent has two genes for black, the bird is said to be homozygous for black, which simply means that its zygote contains

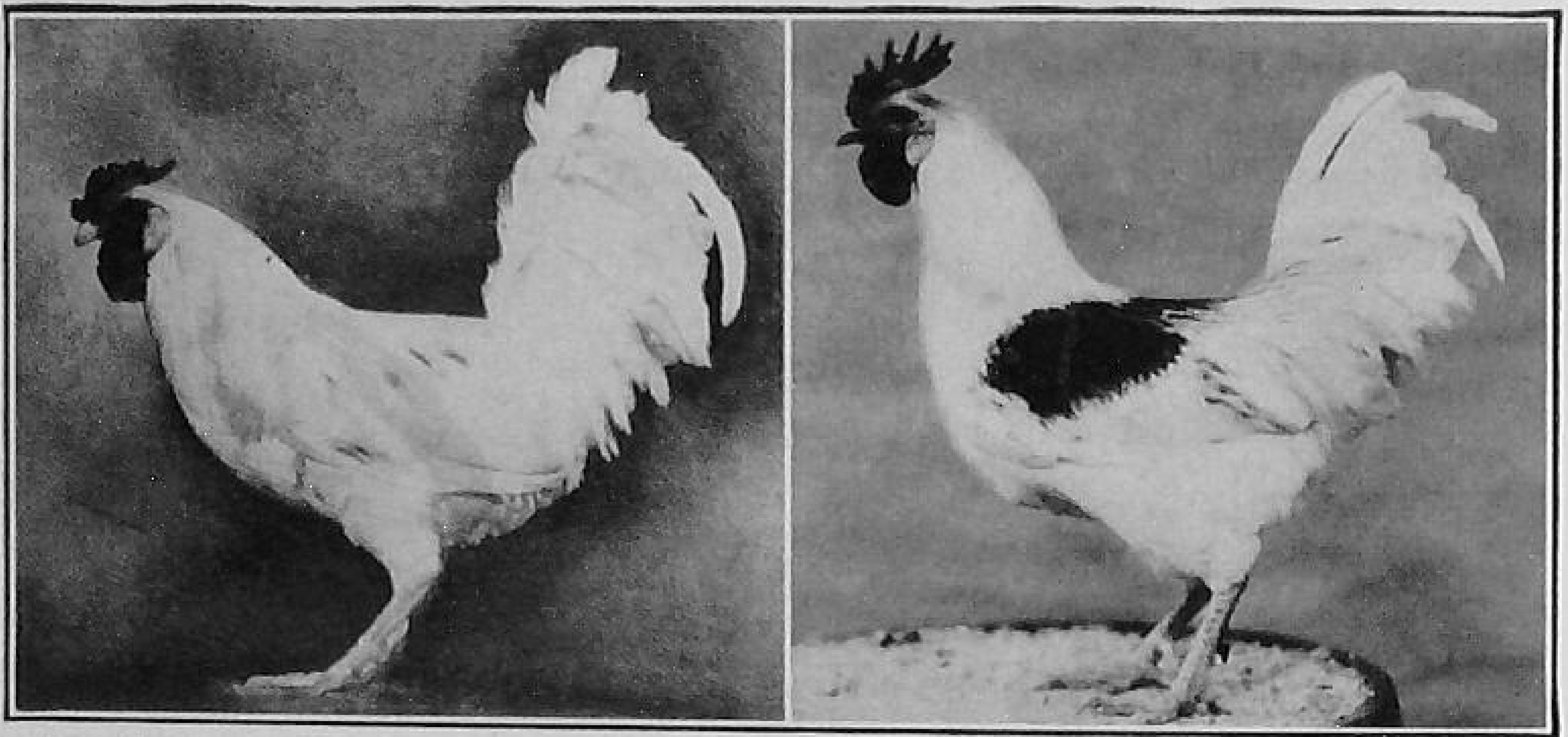


FIG. 41. Left, an F_1 male secured from a mating of a White Leghorn sire and a Black Hamburg dam. Note the few black feathers, indicating that the white of the White Leghorn is not completely dominant to black. Right, an F_1 male secured from a mating of a Rhode Island Red sire and a White Leghorn dam, indicating that the white of the White Leghorn is less dominant to red color than to black color.

two similar genes for the character that is expressed. Since the white parent has two genes for white, the bird is said to be homozygous for white, which simply means that its zygote contains two similar genes for the character that is expressed.

When the black parent is crossed with the white parent, the birds of the F_1 generation each inherit one of the genes for black from the black parent and one of the genes for white from the white parent. The birds of the F_1 generation are all black because black in this cross is dominant to white, but they are heterozygous for black and for white because each received one gene for black from the black parent and one gene for white from the white parent, the term "heterozygous" simply meaning zygotes that contain dissimilar genes.

The two basic principles of Mendelian inheritance are: (1) the principle of the segregation of the genes and (2) the principle of the independent assortment of the genes.

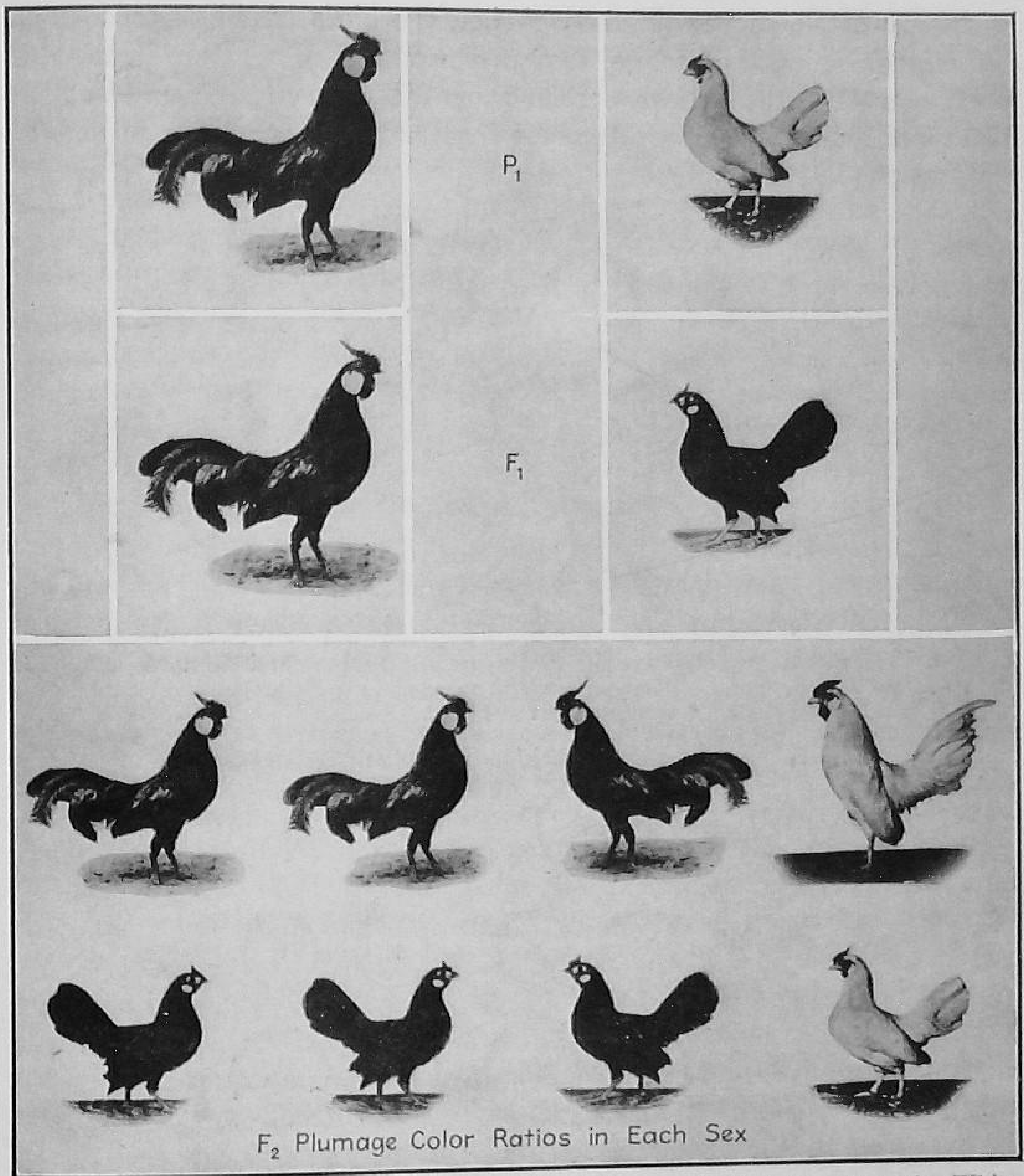


FIG. 42. The results secured from mating a Black Rose-comb Bantam male and a White Rose-comb Bantam female show that the F_1 progeny are black, showing that in this cross white is recessive to black. In the F_2 generation, the proportion of 3 black birds to 1 white bird in each sex demonstrates that segregation of the genes for black and for white took place following the mating of the F_1 birds. The results secured also demonstrate that recombination of the genes for white took place, since white birds were secured from black parents. Similar results would be secured if the original parents were a White Rose-comb Bantam male and a Black Rose-comb Bantam female because the genes for black and for white are not sex-linked.

The Principle of Segregation. When the birds of the F_1 generation are mated among themselves, they produce an F_2 generation in the proportion of 3 blacks to 1 white. The genes for two contrasting characters, black and white, which are brought together in F_1 segregate in definite proportions in F_2.

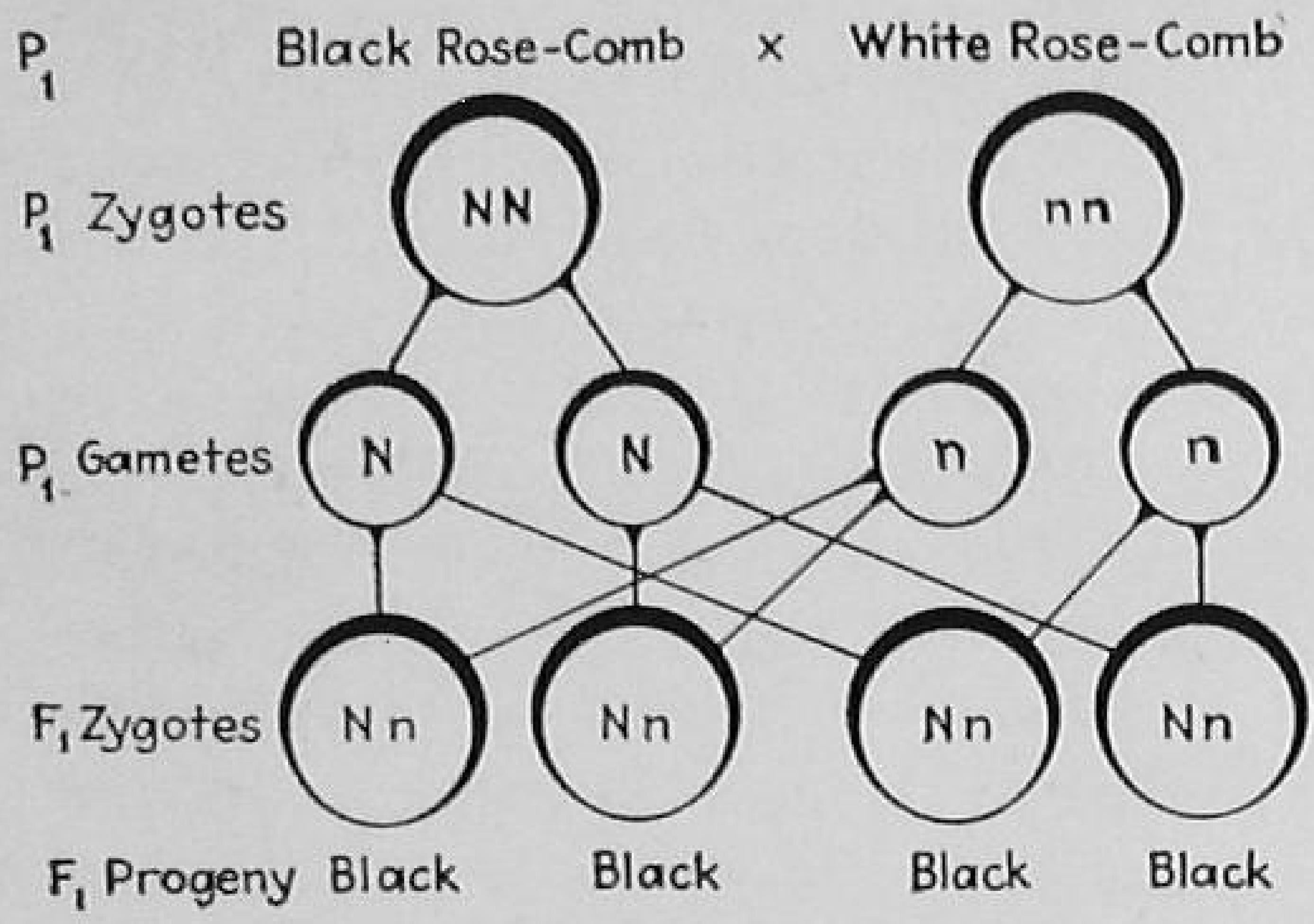


FIG. 43. The parental zygotes give rise to the parental gametes, and the gametes unite in pairs to form the F_1 zygotes. The zygotes, *Nn*, represent the F_1 progeny, all being black because in this cross black, *N*, is dominant to white, *n*.

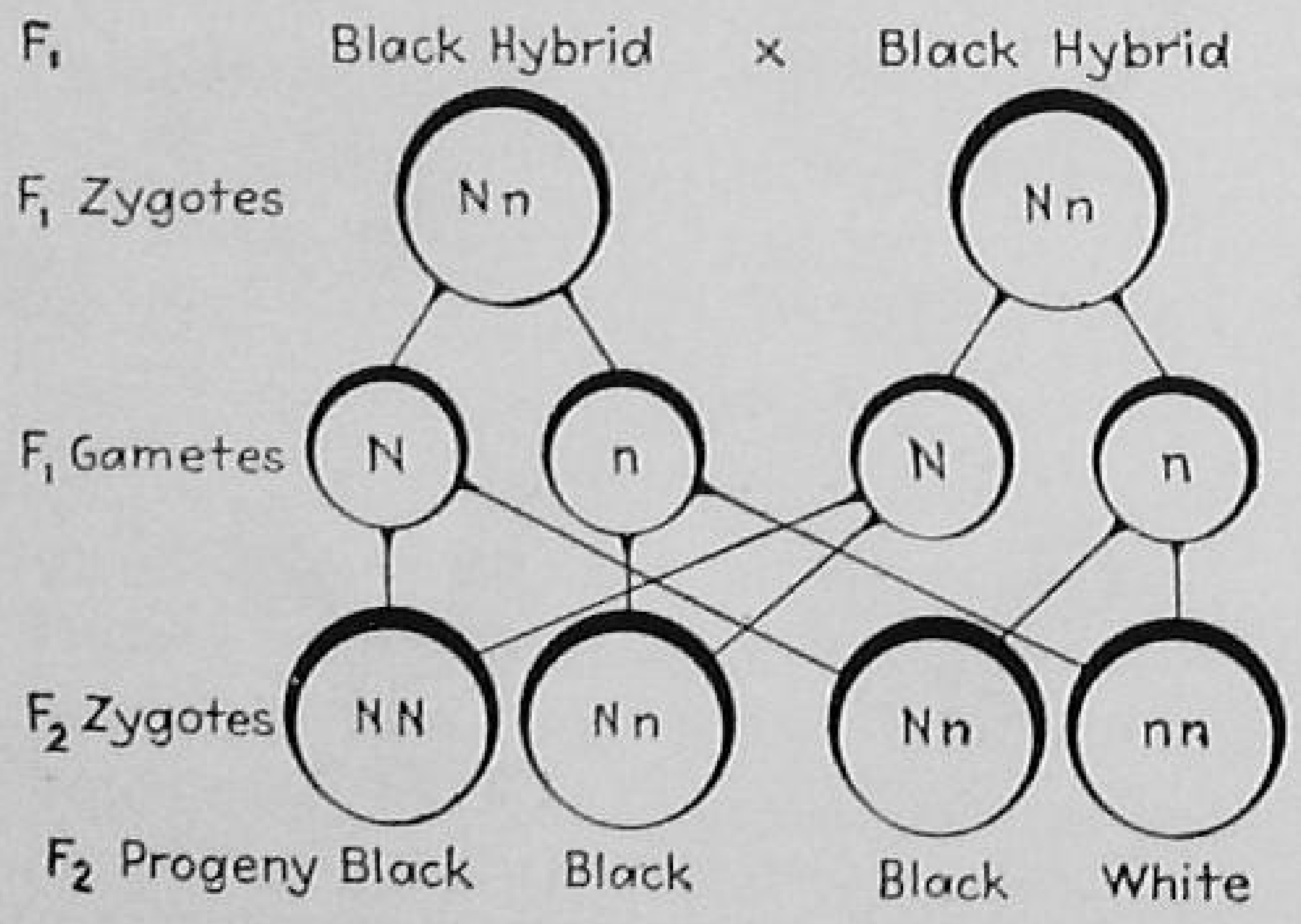


FIG. 44. The F_1 zygotes give rise to the F_1 gametes, which unite in pairs to form the F_2 zygotes, which represent the F_2 progeny. The color of the progeny is in the proportion of 3 blacks to 1 white. It is observed that among the blacks, one is homozygous and two are heterozygous for color. The homozygous black and the homozygous white are the same kind of birds as the original parents (see P_1 zygotes in Fig. 43).

Although the F_2 generation is comprised of 3 blacks to 1 white, the blacks differ among themselves in respect to the results they produce when they are bred. Among the blacks, one-third are homozygous whereas the other two-thirds are heterozygous for black. The F_2 white birds are homozygous recessives and, therefore, produce nothing but white progeny when bred among themselves. The F_2 ratio of 3 blacks to 1 white is really a ratio of 1 homozygous for black to 2 heterozygous

for black and for white to 1 homozygous for white. It should be observed that the F_2 homozygous black is just as pure for black as is its black grandparent, although the parents of the F_2 blacks had a gene for white as well as for black. Likewise, the F_2 homozygous white is just as pure for white as its white grandparent, in spite of the fact that the F_2 white bird's parents were black.

The demonstration of the segregation of the genes in the F_2 generation is the first of two basic principles of Mendelian inheritance.

The Principle of Independent Assortment. This second principle is illustrated clearly in the inheritance of two pairs of characters, which is precisely the same in principle as the inheritance of one pair of characters, *e.g.*, black plumage and white plumage, which has just been discussed.

When two pairs of characters are involved, the birds of the F_1 generation are able to produce four kinds of gametes instead of only two, as in the inheritance of one pair of characters. Since four kinds of gametes are produced by each sex, the possibilities for the segregation and recombination of the genes is four times as great as in the case when only two kinds of gametes are formed.

A cross between a Single-comb Black Leghorn of either sex and a Rose-comb White Minorca of the opposite sex produces an F_1 generation of rose-comb black birds because rose comb is dominant to single comb and black is dominant to white, in this cross. When birds of the F_1 generation are mated among themselves, they produce an F_2 generation of four kinds of birds, as far as comb type and plumage color are concerned, in the following proportions: 9 rose-comb blacks, 3 rose-comb whites, 3 single-comb blacks, 1 single-comb white. Two new kinds of birds appear in the F_2 generation, the rose-comb blacks and the single-comb white. It should be observed at this time that the same kind of F_2 generation, as far as comb type and plumage color are concerned, would have resulted from an original cross of Rose-comb Black Leghorn of either sex and Single-comb White Minorca of the opposite sex. In other words, the particular combination in which the pairs of genes for the two characters are brought into a cross makes no difference at all in the manner in which they segregate and recombine to produce the F_2 generation.

By using appropriate symbols for comb type and plumage color in the cross between a Single-comb Black Leghorn and a Rose-comb White Minorca, the mode of inheritance of two pairs of characters is readily demonstrated. Capital letters are used for the dominant characters and small letters for the recessives. Since rose comb is dominant to single comb, R represents the gene for rose comb and r the gene for single comb. Since in this cross black is dominant to white, N represents the gene for

black and n the gene for white. The genes being borne in pairs, the Rose-comb White Minorca zygote contains the genes $RRnn$ and the Single-comb Black Leghorn zygote contains the genes $rrNN$.

The White Minorca parent produces Rn gametes, and the Black Leghorn parent produces rN gametes. When these parents are mated, the F_1 zygote contains the genes $RrNn$. The F_1 birds have rose combs and are black. The F_1 male and F_1 female each produce four kinds of gametes: RN, Rn, rN, and rn (see Fig. 45). When an F_1 male is mated with an F_1 female. each of the gametes from the male may mate with

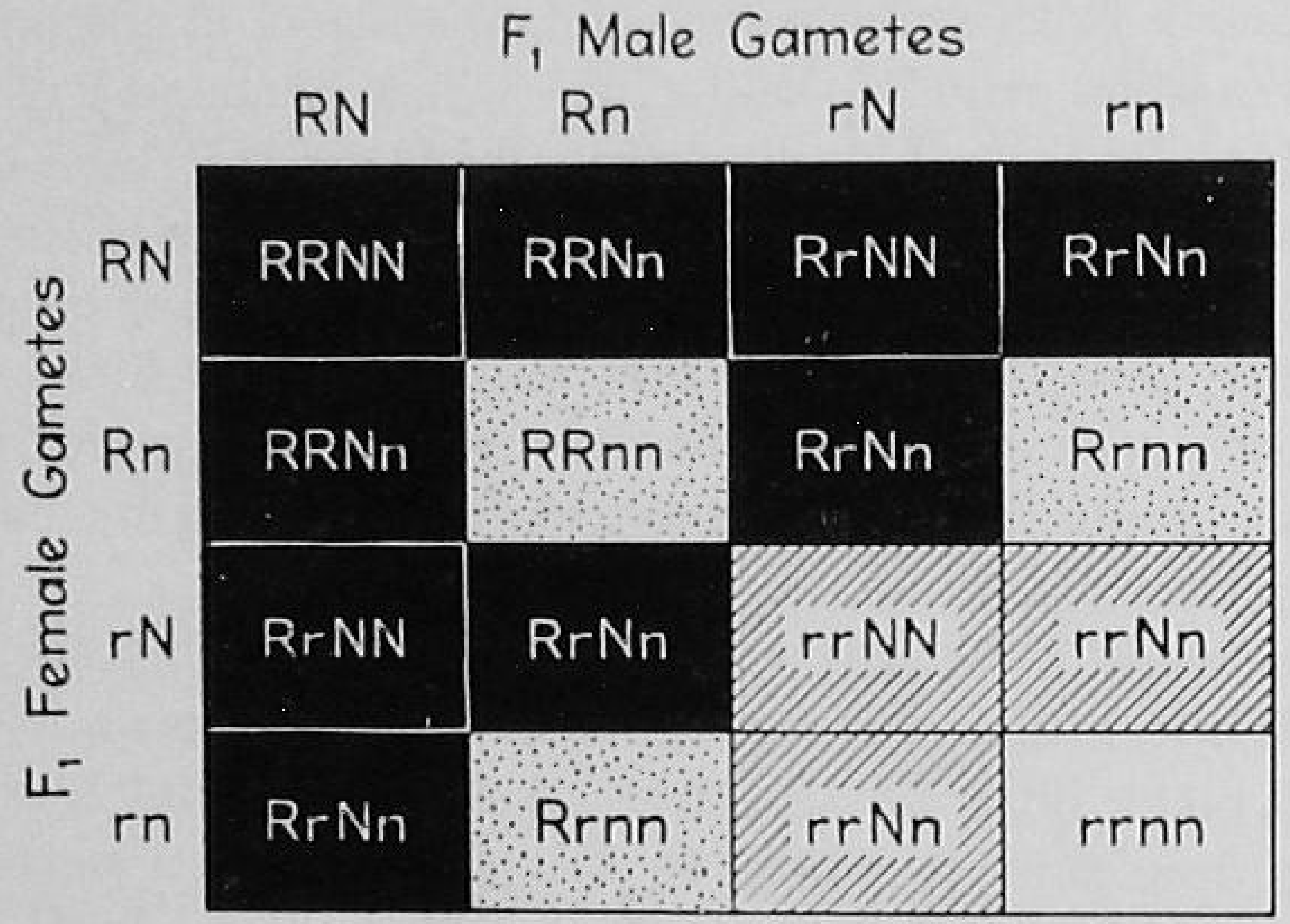


FIG. 45. Showing the F_2 results secured from a mating of an F_1 male $\times$ F_1 female, each secured from a P_1 mating consisting of a Single-comb Black Leghorn, $rrNN$, and a Rose-comb White Minorca, $RRnn$. Both F_1 birds are $RrNn$ and have rose combs and black plumage because rose comb is dominant to single comb, and in this cross black is dominant to white. The F_2 generation consists of a ratio of 9 rose-comb blacks:3 rose-comb whites:3 single-comb blacks:1 single-comb white. The results secured are due to the independent assortment of the genes. Note that the zygotes in the upper left-hand corner and lower right-hand corner represent new combinations of the genes from those present in the P_1 parents.

each of the gametes from the female, so that there are 16 possible combinations. The checkerboard plan of illustrating the kind of zygote formed by the mating of any two gametes is very effective, as shown in Fig. 45. The type of comb and color of plumage of each kind of zygote is indicated in each rectangular space in Fig. 45.

Out of every 16 birds in the F_2 generation, on the average there are 12 rose combs to 4 single combs, a 3:1 ratio, and there are 12 blacks to 4 whites, a 3:1 ratio. Of the 12 rose combs, there are 9 blacks to 3 whites, a 3:1 ratio. Of the 4 single combs, there are 3 blacks to 1 white, a 3:1 ratio. Of the 4 whites, there are 3 rose combs to 1 single comb, a 3:1 ratio.

F_2 Ratio in Relation to Gene Pairs in Original Cross. In crosses in which more than two pairs of independent characters are involved, the

segregation and independent assortment of the genes occur in precisely the same way as in the inheritance of one pair or two pairs of independent characters. It will be recalled that in the case of one pair of characters two kinds of F_1 gametes are formed and in the case of two pairs of characters four kinds of F_1 gametes are formed. The number of the different kinds of gametes formed by the F_1 birds is doubled with each increase in the number of different genes involved.

In the inheritance of three pairs of characters, 8 kinds of F_1 gametes are formed, and in the inheritance of four pairs of characters, 16 kinds of gametes are formed. For each increase in the number of different genes involved, the average number of F_2 individuals required to be produced to secure the appearance of the various combination of characters resulting from the chance combination of the different kinds of F_1 gametes is increased by four, as shown in Table 10.

TABLE 10. AVERAGE NUMBER OF F_2 INDIVIDUALS NECESSARY TO SECURE THE APPEARANCE OF ALL POSSIBLE COMBINATIONS OF CHARACTERS FOR EACH INCREASE IN NUMBER OF DIFFERENT PAIRS OF GENES

No. of different pairs of genes in the cross	No. of different kinds of F_1 gametes produced	F_2 ratio	Average No. of F_2 individuals necessary to secure the appearance of all possible combinations of characters
1	2	3:1	4
2	4	9:3:3:1	16
3	8	27:9:9:9:3:3:3:1	64

SEX-LINKED INHERITANCE

Many characters that fowls possess are inherited equally from sire and dam. The genes giving rise to such characters are borne on the numerous pairs of autosomes common to both sexes, half of the autosomes being of paternal origin and half of maternal origin in the case of each individual chicken.

There are certain characters, however, that are transmitted from the dam to her sons but not to her daughters, although these same characters are transmitted from the sire to his sons and daughters alike. Characters that are transmitted from dam to son only are called sex-linked characters because the genes that determine such characters are borne on the sex chromosomes.

The results secured from a mating of a Rhode Island Red male and a Barred Plymouth Rock female serve to illustrate the manner in which sex-linked characters are inherited. The male offspring of such a mating

are barred, and the female offspring are black, although some of the pullets may have red in the neck and breast feathers, but black is the predominant plumage color (see Fig. 46). The fact that the male off-

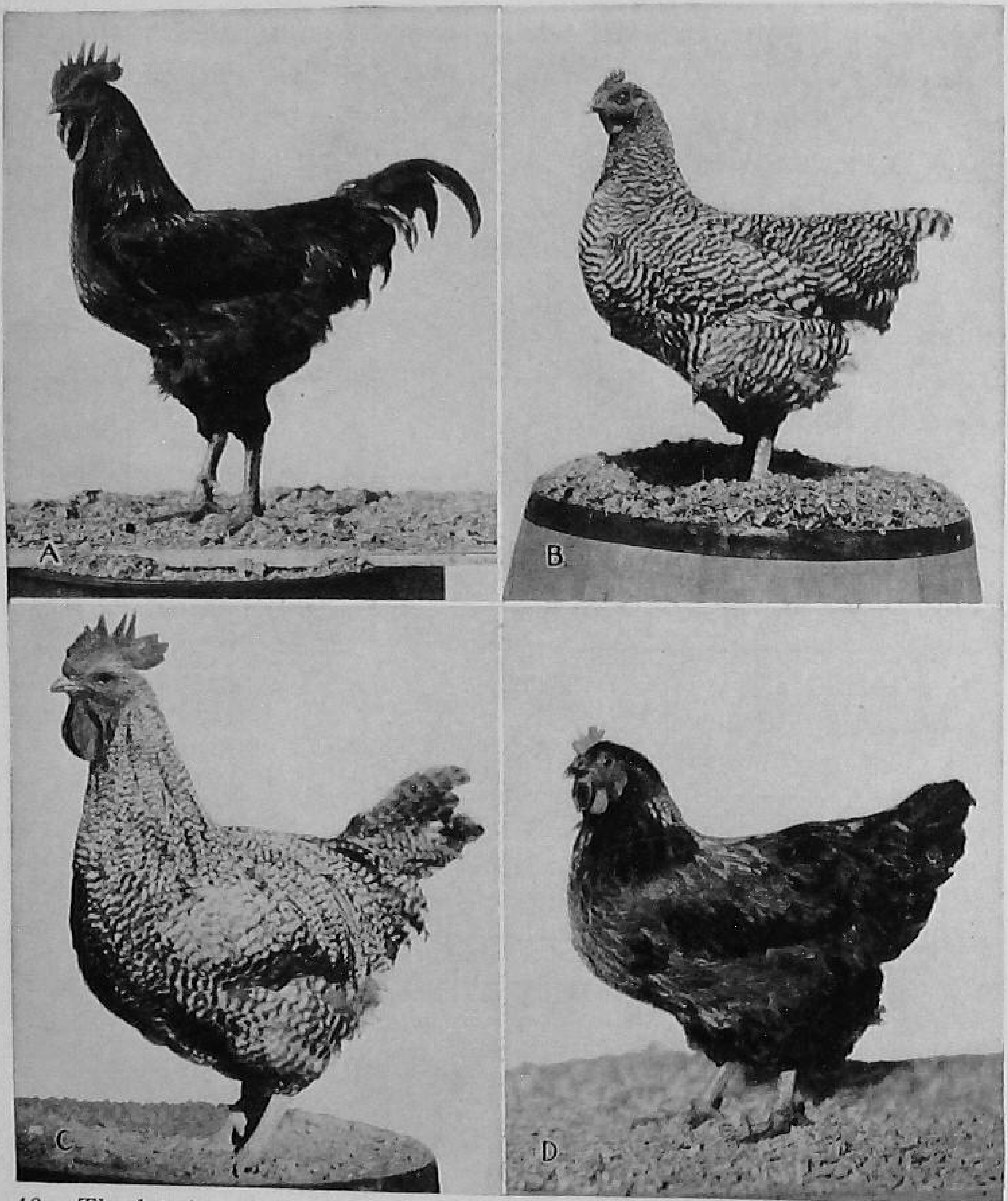


FIG. 46. The barring of the Barred Plymouth Rock is sex-linked. Since the female is heterozygous for sex and has one sex chromosome only, it is transmitted to her sons but not to her daughters, so that her adult sons are barred but her adult daughters are black, although some of them may have some red in the neck feathers. (*A*) Rhode Island Red sire; (*B*) Barred Plymouth Rock dam; (*C*) barred son; (*D*) black daughter. (*U.S. Dept. Agr.*)

spring only of this mating are barred demonstrates that the gene that determines the barring pattern in the plumage is borne on the sex chromosome. The Barred Plymouth Rock female's gametes containing the sex chromosome, upon uniting with the Rhode Island Red male's gametes, each of which also contains the sex chromosome, produce male zygotes

inasmuch as they each contain two sex chromosomes. On the other hand, the Barred Plymouth Rock female's gametes, lacking the sex chromosome, upon uniting with the Rhode Island Red male's gametes, each

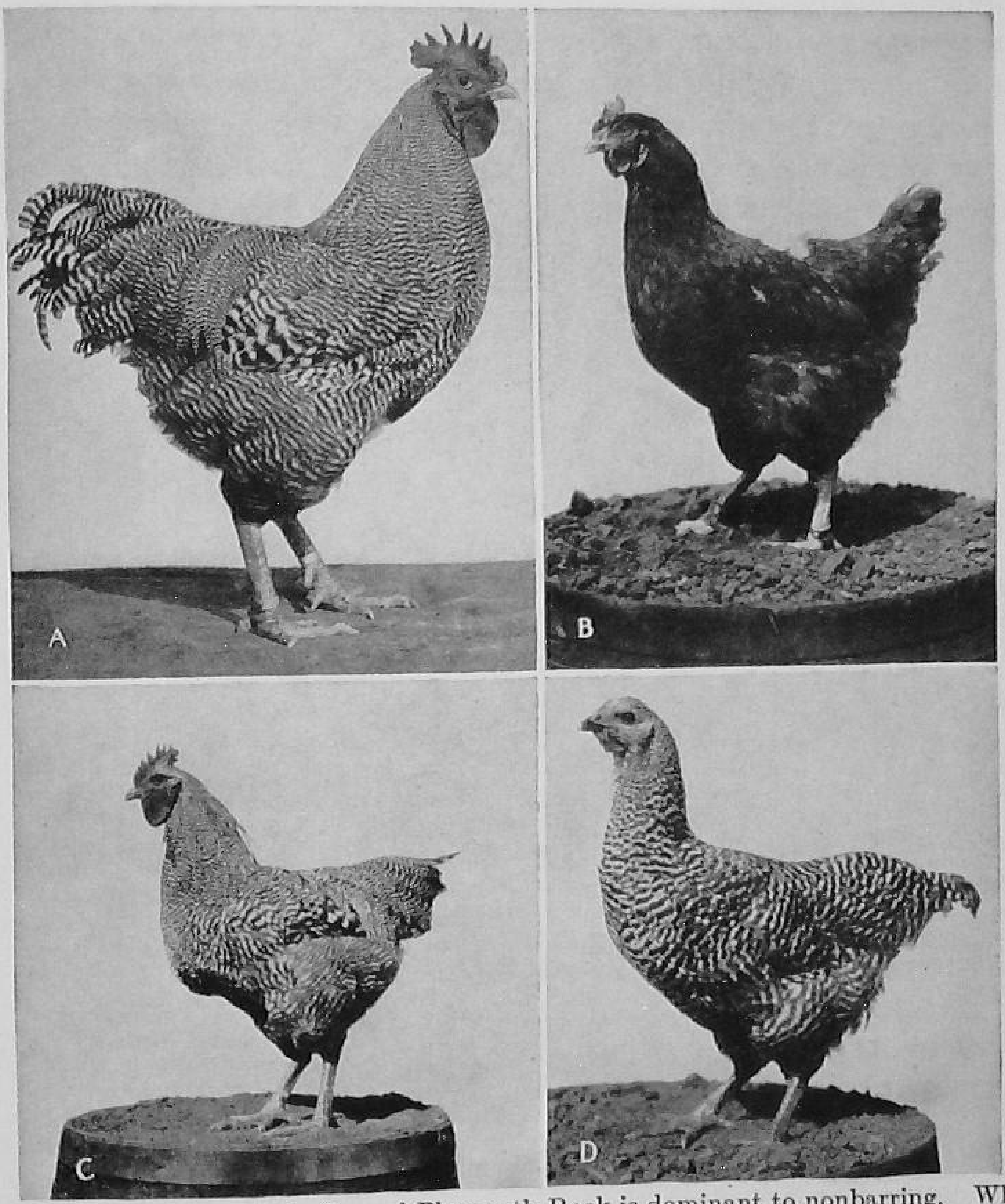


FIG. 47. The barring of the Barred Plymouth Rock is dominant to nonbarring. When a Barred Plymouth Rock male is mated to a Rhode Island Red female, the sons and daughters are barred because the sire has a gene for barring on each of his two sex chromosomes, one of which is transmitted to each of his sons and the other to each of his daughters. (*A*) Barred Plymouth Rock sire; (*B*) Rhode Island Red dam; (*C*) adult son; (*D*) adult daughter.

of which contains the sex chromosome, produce female zygotes, inasmuch as they each contain only one sex chromosome.

Barring is sex-linked and is transmitted from the barred female parent to her male offspring only. The gene for barring is dominant to the gene for nonbarring, as in the Rhode Island Red male. The term "dominant" simply means that the effects produced by one gene suppress the effects

of another gene. Barring is said to be dominant to nonbarring. In illustrating the results secured from matings, the capital letter is always used to denote the dominant character, so that *B* is used to denote barring, and *b* nonbarring, the latter being the recessive character.

Since the gene for barring is borne on the sex chromosome, the gene *B* is shown separate from the autosomes in diagrams illustrating sex-linked inheritance (see Fig. 48). Since the Rhode Island Red is nonbarred, the male zygote is designated as "38 + *b* and 38 + *b*." The male zygote produces one kind of gametes only, "38 + *b*." The zygote of Barred Plymouth Rock female is designated "38 + *B* and 38" (see Fig. 48).

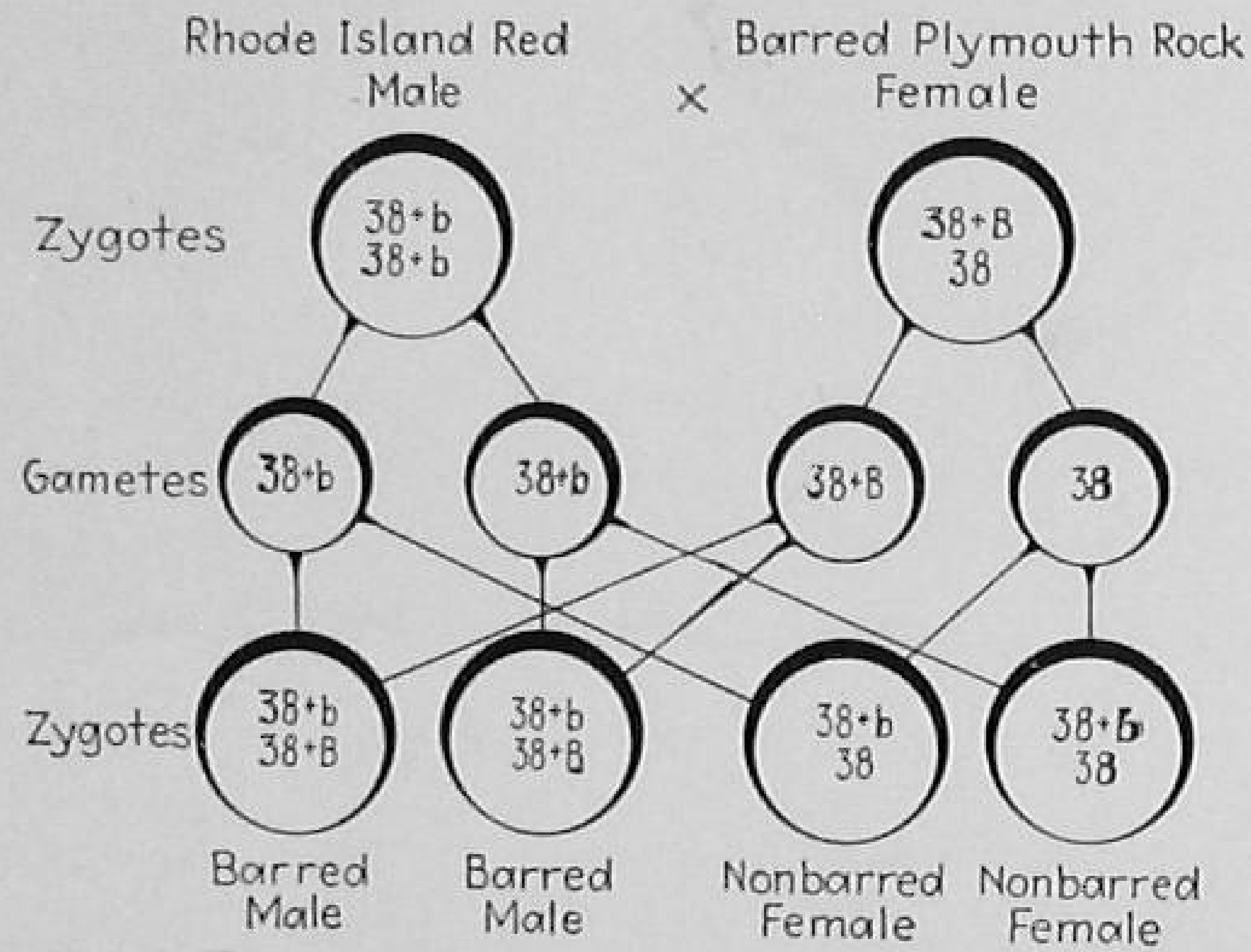


FIG. 48. The Rhode Island Red male has 38 pairs of autosomes and 2 sex chromosomes, associated with each of which is the gene *b* for nonbarring. The Barred Plymouth Rock female has 38 pairs of autosomes but only one sex chromosome, associated with which is the sex-linked gene *B* for barring, which is dominant to nonbarring. The male progeny are barred, whereas the female progeny are nonbarred.

This female zygote produces two kinds of gametes, "38 + *B*" and "38" (see Fig. 48).

The gametes "38 + *b*" from the male upon uniting with the gametes "38" from the female produce "38 + *b* and 38" zygotes, which develop into nonbarred (black) females because the gene for barring is lacking and there is only one sex chromosome present. The gametes "38 + *b*" from the male upon uniting with the gametes "38 + *B*" from the female produce "38 + *b* and 38 + *B*" zygotes, which develop into barred males because the gene for barring is present and two sex chromosomes are also present. The gene for barring is sex-linked, since it is transmitted from the barred dam to her male offspring only. A true test of the sex linkage of the gene for barring is to mate a Rhode Island Red male to some of the nonbarred (black) females obtained from the original cross (Rhode Island Red male × Barred Plymouth Rock female); the offspring, both

male and female, of this backcross mating are nonbarred, showing that the nonbarred (black) females did not carry the gene for barring.

When a Barred Plymouth Rock male is mated with a Rhode Island Red female, all the offspring, both male and female, are barred. The zygote of the Barred Plymouth Rock male "38 + *B* and 38 + *B*" produces one kind of gametes only, "38 + *B*" (see Fig. 49). The zygote of the Rhode Island Red female "38 + *b* and 38" produces two kinds of gametes, "38 + *b*" and "38" (see Fig. 49).

The gametes "38 + *B*" from the male upon uniting with the gametes "38" from the female produce "38 + *B* and 38" zygotes, which develop

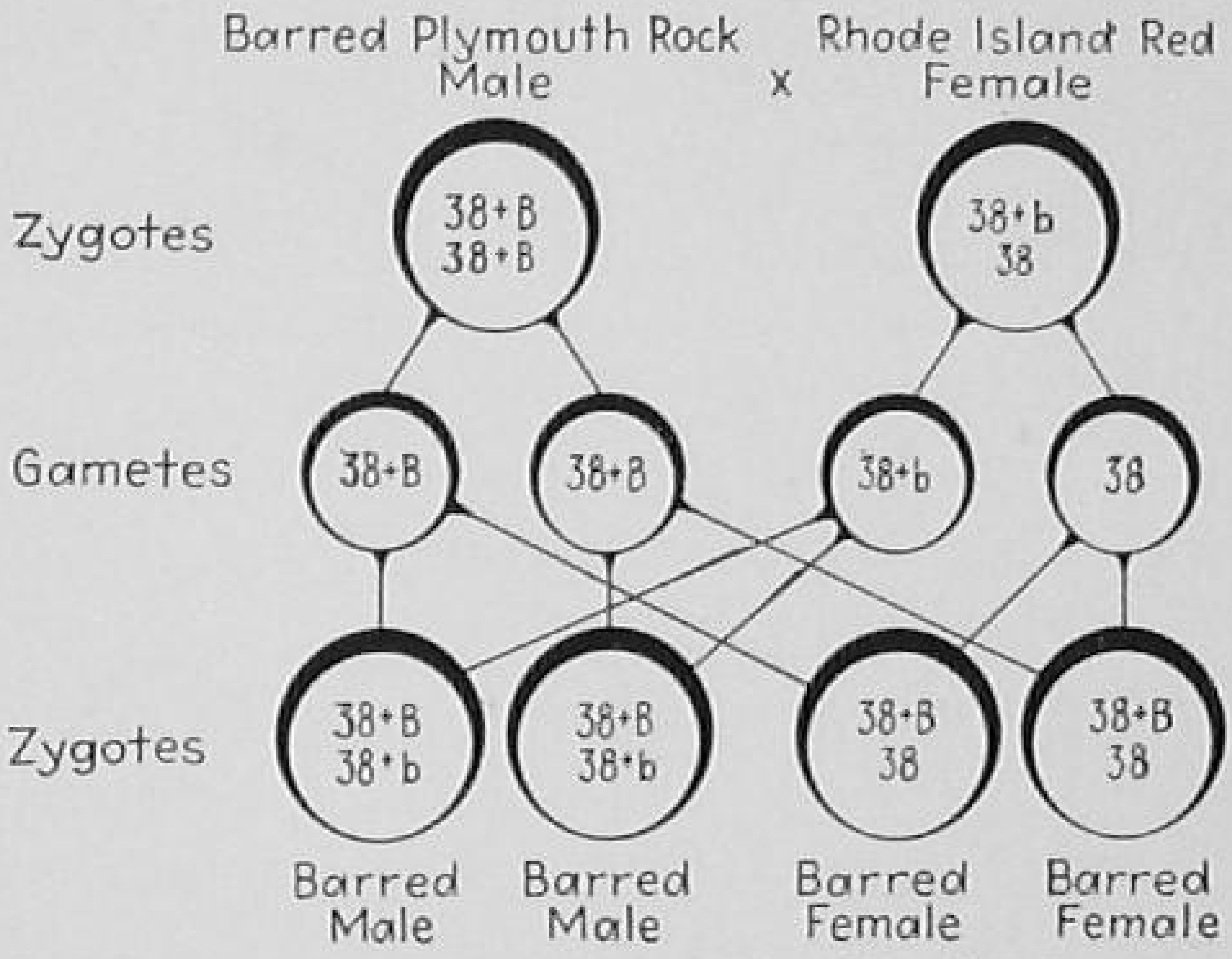


FIG. 49. The Barred Plymouth Rock male has 38 pairs of autosomes and 2 sex chromosomes, associated with each of which is the sex-linked gene *B* for barring. The Rhode Island Red female has 38 pairs of autosomes but only one sex chromosome, associated with which is the gene *b* for nonbarring. The male and female progeny are barred, demonstrating that barring is dominant to nonbarring.

into barred females because the gene for barring is present and there is only one sex chromosome present. The gametes "38 + *B*" from the male upon uniting with the gametes "38 + *b*" from the female produce "38 + *B* and 38 + *b*" zygotes, which develop into barred males because the gene for barring is present and two sex chromosomes are also present. The Barred Plymouth Rock male transmits the gene for barring to his daughters as well as his sons.

Distinguishing Sex at Hatching Time. An interesting feature about the inheritance of some of the sex-linked characters is that the sexes of the chicks can be distinguished at hatching time.

Color of Progeny in Sex-linked Barring Matings. The males of several different breeds and varieties may be mated with Barred Plymouth Rock females for the purpose of producing chicks which, at hatching time, can be separated according to sex by the down pattern (see Table 10). The adult plumage of the sexes also differs markedly (see Fig. 46).

Distinguishing Sex of Purebred Barred Plymouth Rock Chicks. In a strain of purebred Barred Plymouth Rocks in which the males were lighter colored, it was found that the sex of the chicks produced could

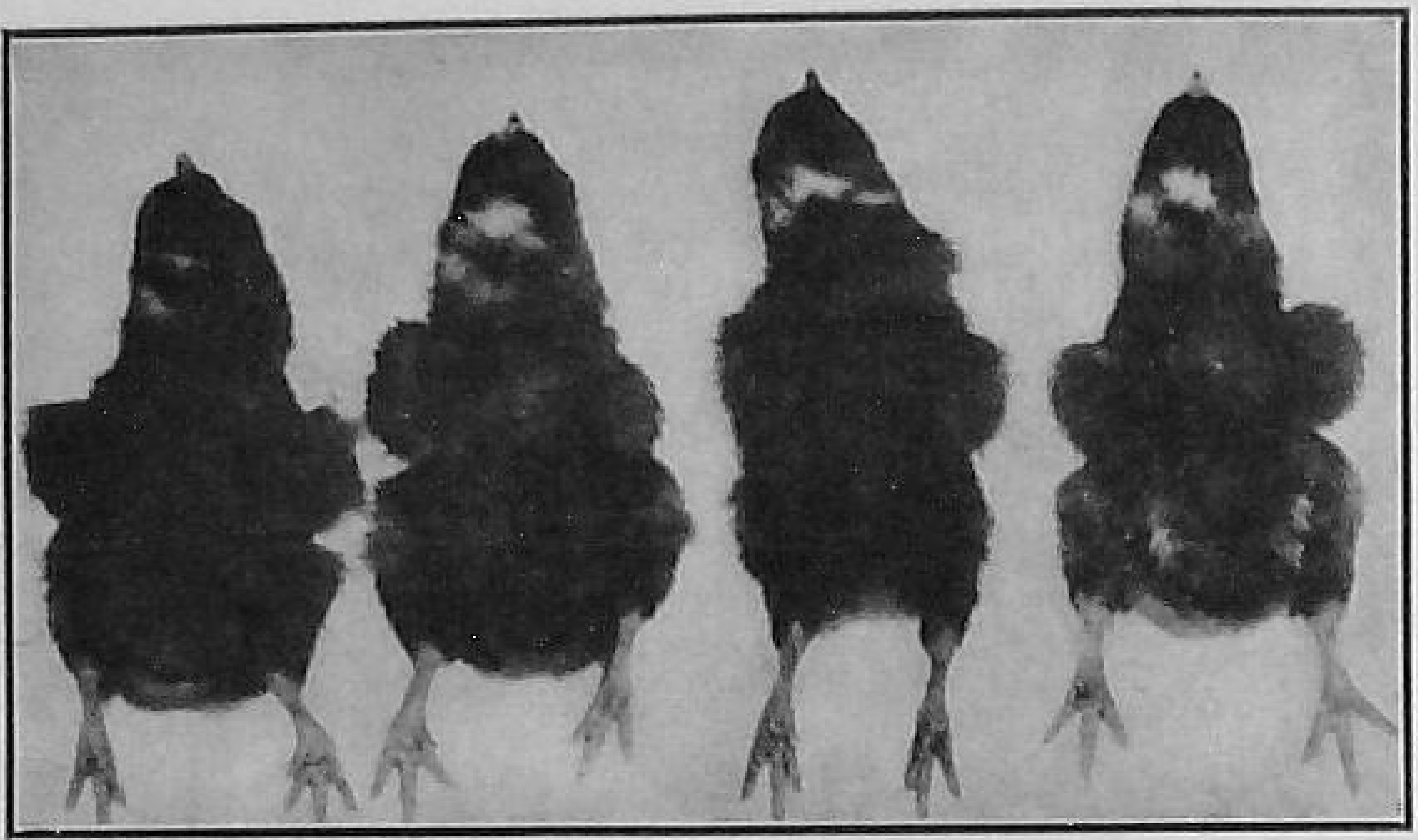


FIG. 50. Typical head spots in purebred Barred Plymouth Rock male chicks. Although the head spots vary in size, they tend to be blunt anteriorly, and have a scattering of flecks of light-colored down laterally and posteriorly. (*F. N. Jerome.*)

be determined with a high degree of accuracy by a careful examination of the head spots (see Figs. 50 and 51).

Distinguishing Sex of Purebred Rhode Island Red Chicks. The sex of purebred Rhode Island Red chicks at hatching time can be determined with a relatively high degree of accuracy by careful examination of the

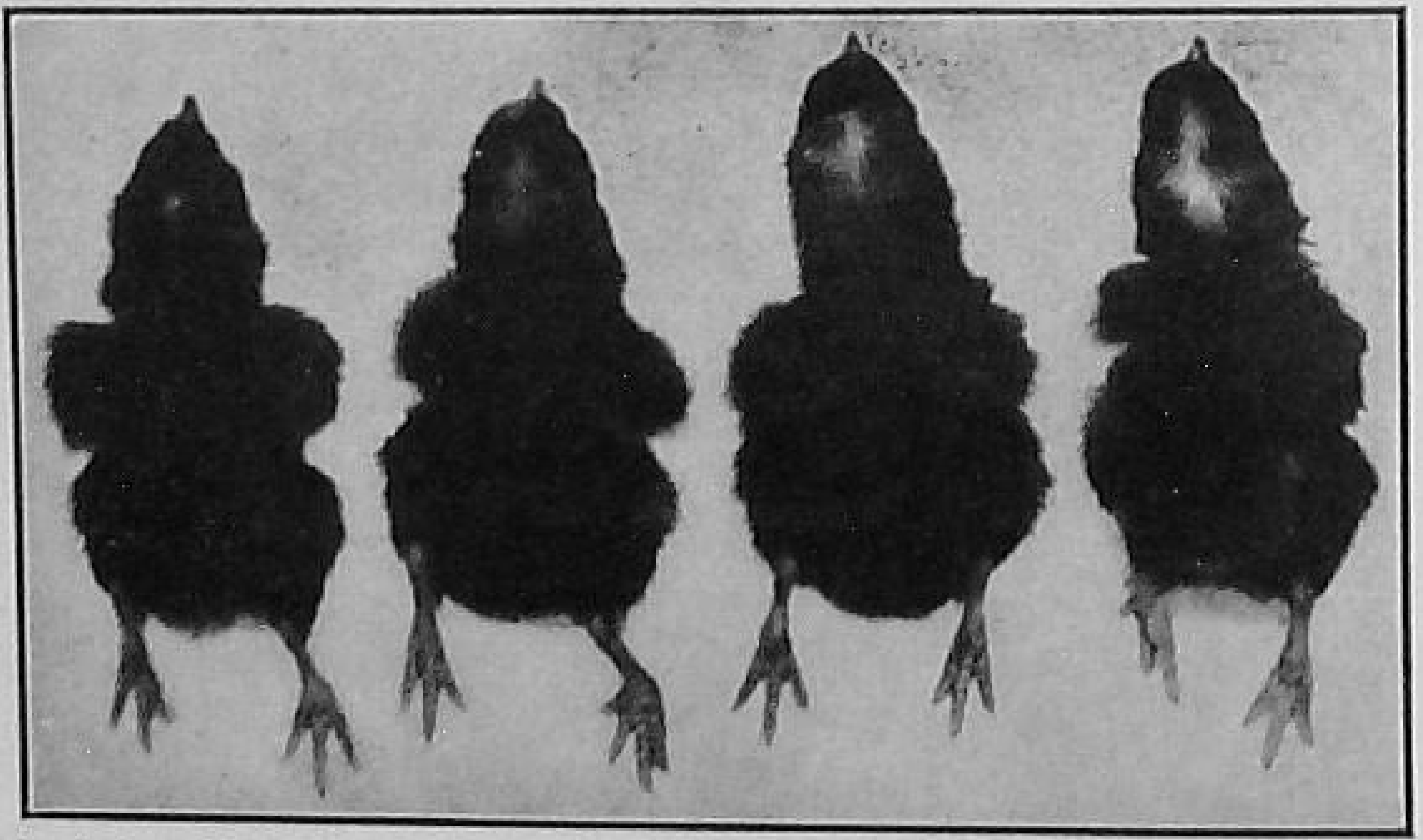


FIG. 51. Typical head spots in purebred Barred Plymouth Rock female chicks. The head spot is more regular in outline than in male chicks. In female chicks, the head spot is somewhat oval in shape, pointed anteriorly, with a median line of the lightest down running from the front to the back of the spot, and the light-colored down fading gradually into the black down laterally from the median line. (*F. N. Jerome.*)

down color over the wing. Male chicks have a relatively large white spot in the web region of the dorsal wing surface, whereas female chicks have a uniform red color in this region. By selecting chicks on this basis and using them for future breeding purposes, it should be possible

to develop a strain in which most of the chicks produced each year could be "sexed" accurately.

"Silver" Sex-linked. Another kind of sex-linked cross that enables the sex of chicks to be distinguished at hatching time is the "gold" and "silver" cross. The two terms refer to two well-known ground colors of the down of the chicks of several different breeds and varieties. To the gold class belong those breeds and varieties in which the ground color of the down is some shade of buff or golden brown, such as Buff Plymouth Rock and Rhode Island Red. Also belonging to this class are those breeds or varieties in which the adult male is black-red in plumage color,

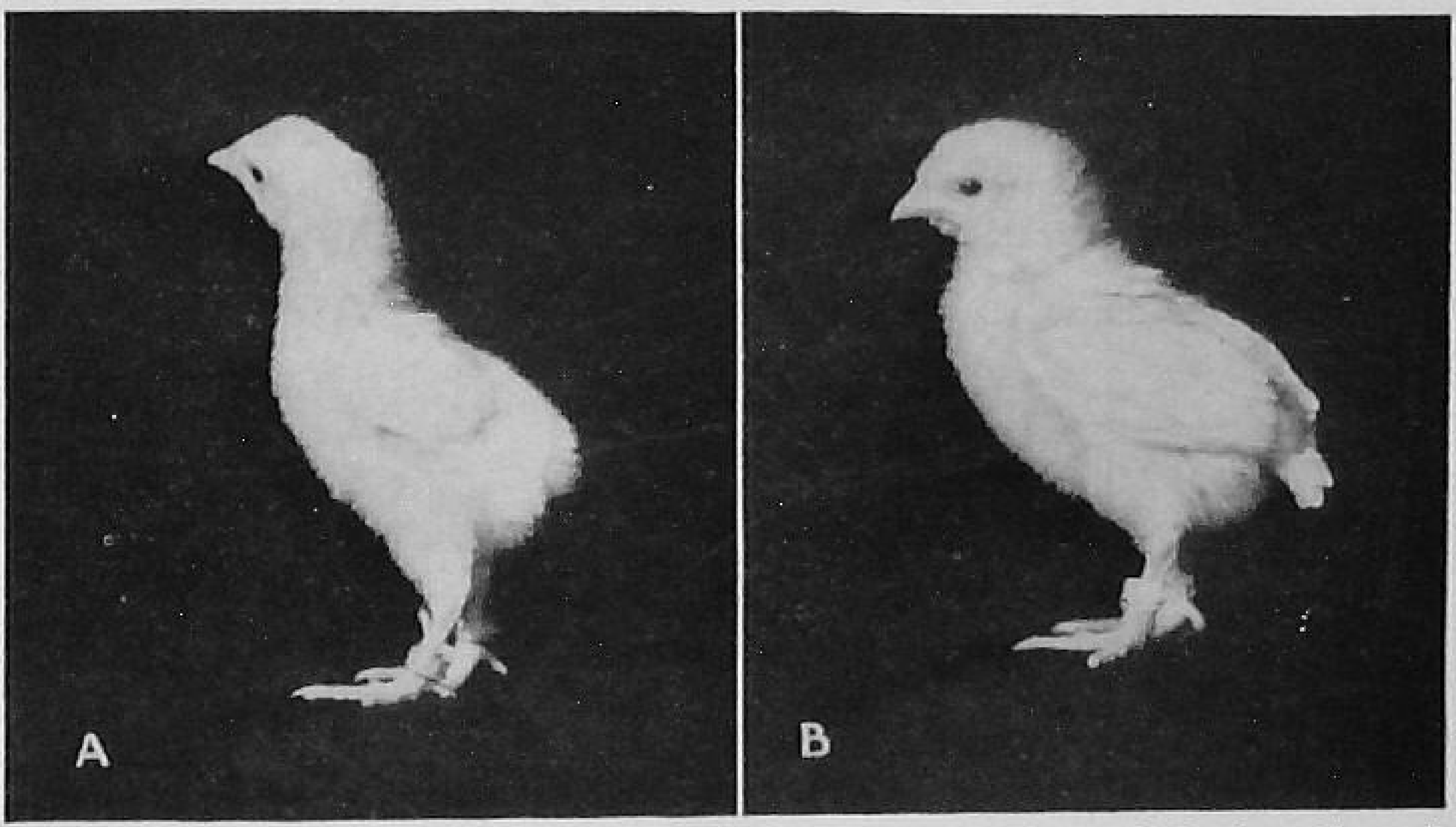


FIG. 52. Late feathering is dominant to early feathering and is sex-linked, so that when a White Leghorn male is mated to a general-purpose female, the sons are late feathering, as shown in (*A*), and the daughters are early feathering, as shown in (*B*). The best time to determine whether chicks are late feathering or early feathering is at hatching time by counting the number of well-developed secondaries. This is discussed in the next chapter.

such as Brown Leghorn and Golden-laced Wyandotte. To the silver class belong those breeds and varieties in which the ground color of the down is creamy silver, such as Light Brahma and Columbian Plymouth Rock. The gene for silver is sex-linked and dominant to gold.

Late Feathering Sex-linked. Still another kind of cross can be made that permits the separation, at hatching time, of the chicks according to sex. It is well known that purebred Leghorn chicks acquire their first feathers, especially wing and tail feathers, sooner than many strains of purebred chicks of such breeds as Brahmas, Plymouth Rocks, Rhode Island Reds, and Orpingtons. The relatively later feathering characteristic of the Asiatic, American, and English breeds is sex-linked, so that if the females of these breeds are mated with Leghorn males the chicks can be assorted as to sex at hatching time by the stage of the growth of the wing feathers. The male chicks show very little wing-feather

development, whereas the female chicks show wing-feather development. Late feathering is dominant to early feathering. At least seven visible secondaries at hatching time are also an index of early feathering.

Sex linkage of late feathering is well illustrated by tail-feather development at 10 days of age (see Fig. 52). When an early-feathering male is mated to a late-feathering female, the cockerels secured from this mating are late feathering and the pullets are early feathering. In this mating, the female transmits late feathering to her sons, but not to her daughters. Well-developed tail feathers at 10 days of age are an index of early feathering, as shown in Fig. 52.

Sex-limited Inheritance. As distinguished from sex-linked inheritance, sex-limited inheritance refers to the inheritance of certain characters specific to each sex. Males alone inherit the ability to crow, and except for certain hen-feathered breeds, males alone inherit hackle and sickle feathers. Females alone inherit the ability to cackle and lay eggs. These are but a few examples of sex-limited inheritance.

GENES WITH VARIOUS EFFECTS

Modifying Genes. Several genes may be the determiners of a single character, one gene being primarily responsible for the development of the character, while the other genes affect the degree of development or otherwise modify the expression of the principle gene; such genes are called "modifying genes."

Linked Genes. Certain cases illustrating the fact that segregation and independent assortment of some genes do not take place are those in which certain characters possessed by a bird used in an original cross tend to remain associated with each other in the F_2 generation. This is due to the fact that the genes giving rise to these characters are on the same chromosome and so do not assort independently. The phenomenon is known as "linkage," and research studies have shown that the genes for single comb and for the Creeper condition exhibit linkage, as well as the genes for crest, frizzling, and dominant white. In so far as available evidence is concerned, linkage is of relatively little importance to poultry breeders, but there is a possibility that linkage may be shown between genes for certain structural characters and genes for certain physiological characters, such as egg production. The linkage of genes should not be confused with sex-linked inheritance. A corollary phenomenon of linkage is that of crossing over, which takes place as the result of an interchange of parts of the same pair of chromosomes.

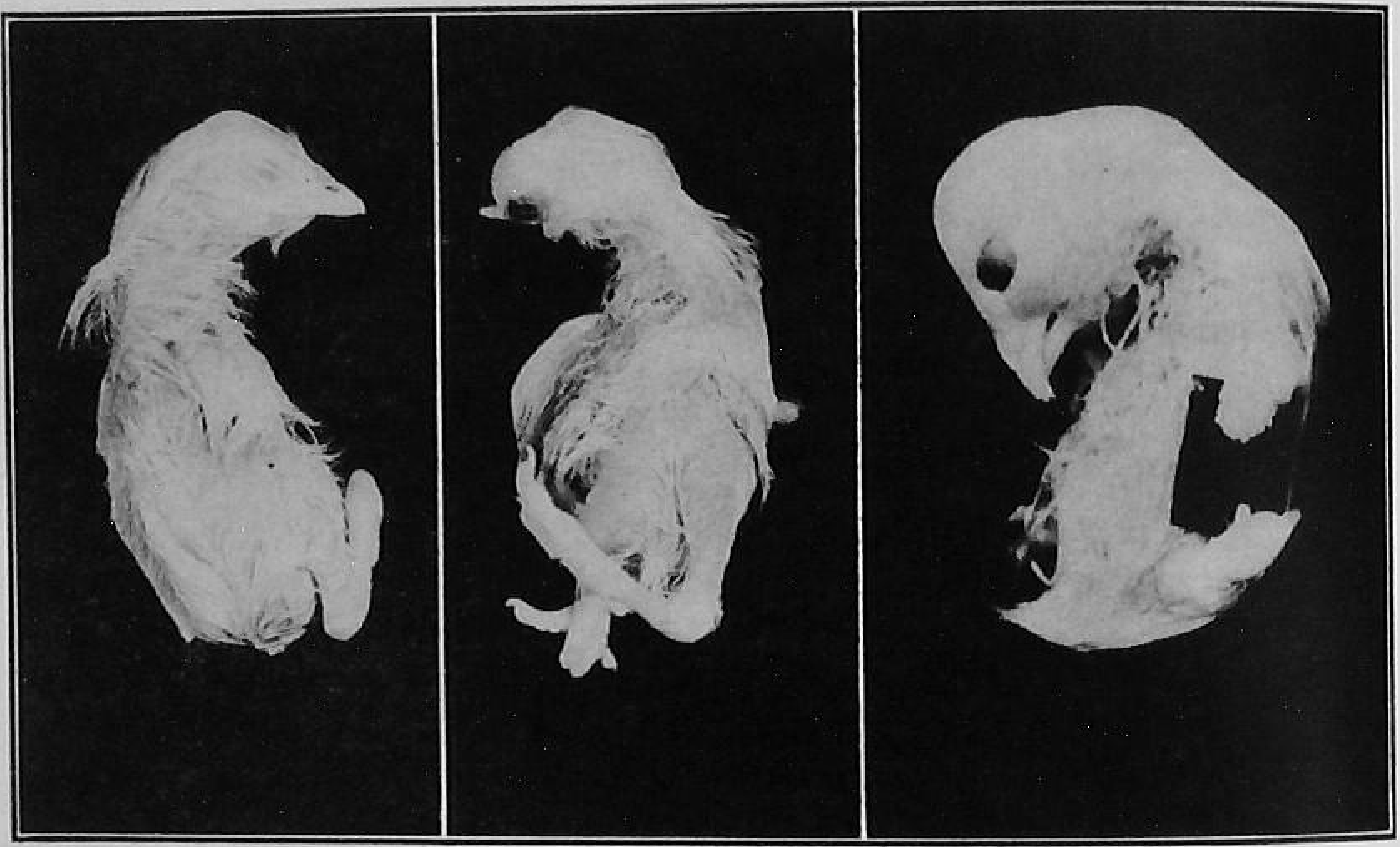
Lethal Genes. One of the surprising things revealed in recent studies on inheritance is the existence of genes that, when in a homozygous condition, kill the chick embryo.

TABLE 11. SEX-LINKED CROSSES FOR THE PRODUCTION OF CHICKS THAT CAN BE DISTINGUISHED ACCORDING TO SEX AT HATCHING TIME
(Adapted from Warren, 1930)

Nonbarred males	*Barred females*	*Color of chick*	*Color of adult progeny*
1. Black varieties	Barred Plymouth Rock	Males black on top of body except white spot on head. Beak, shanks, and toes yellow Females all black on top of body. Beak, shanks, and toes very dark	Males barred. Beak, shanks and toes yellow Females black. Beak, shanks, and toes very dark
2. Rhode Island Red, Buff Plymouth Rock, Brown Leghorn, and all other black-red color varieties	Barred Plymouth Rock	Same as chick in No. 1	Same as in No. 1, except females may show red or gold on neck or breast
3. Most white varieties except White Leghorn and White Plymouth Rock	Barred Plymouth Rock	Same as chick in No. 1	Same as in No 1
Gold males	*Silver females*	*Color of chick*	*Color of adult progeny*
4. Rhode Island Red	White Wyandotte. All Columbian pattern varieties. All Silver-laced and Silver-penciled varieties	Males cream or white, may show narrow striping Females buff or red, may show narrow striping	Males Columbian plumage pattern Females buff or red, may show some stippling or striping
5. Buff varieties	Same as in No. 4	Same as in No. 4 except females are usually lighter in color	Same as in No. 4, except females usually buff
6. Brown Leghorn and other black-red color varieties	All Columbian pattern varieties	Same as in No. 4	Same as in No. 4
Early-feathering males	*Late-feathering females*	*Chick wing feathering*	*Adult wing feathering*
7. Leghorn and other Mediterranean breeds	Many strains of American, Asiatic, and English breeds	Males none or very few secondaries Females at least 7 visible secondaries at hatching time	No differences between sexes in adult wing feathering

Cornish chickens are heterozygous for a gene for relatively short shanks. This gene in a homozygous condition causes the death of the embryo during the last week of incubation.

Creeper chickens are heterozygous for the "Creeper" gene, and embryos having this gene in a homozygous condition die during the first week of the incubation period. There are numerous lethal and sub-lethal genes which affect the development of the beak and other organs and the development and structure of feathers.



A *B* *C*

Fig. 53. (*A*) normal embryo. (*B*) abnormal embryo due to a lethal gene which affects both mandibles, the lower mandible being almost entirely absent, and the upper mandible much reduced in size, frequently pointing upward. The gene responsible for this condition is an autosomal recessive. (*D. R. Marble, J. A. Harper, and E. V. Hammers*, 1944.) (*C*) a homozygous Creeper embryo at 19 days of age. (*W. Landauer*, 1941.)

Mutations. Occasionally, a new character appears unexpectedly and is subsequently found to be inherited. Such a sudden heritable variation is called a "mutation" and is due to a change in one or more genes.

Genotype and Phenotype. The term "genotype" refers to the genetic constitution of a bird, whereas "phenotype" refers to the visible characters of the bird. Birds of the same phenotype may be of different genotypes. For instance, the F_2 generation of a cross between a Black Rose-comb and a White Rose-comb Bantam is comprised of the proportion of 3 blacks to 1 white, and among every three blacks one is homozygous for black whereas the other two are heterozygous for black. The three blacks belong to the same phenotype, but the homozygous black belongs to one genotype, and the heterozygous blacks belong to another genotype.

Dominant and Recessive Characters. Some of the characters for which the mode of inheritance has been determined are listed in Table 12.

Most of the characters listed in Table 12 which have been found to be inherited in typical Mendelian manner are, for the most part, simple characters. The listing of the known dominant and recessive characters is a matter of convenience to the readers of this book and is impressive from the standpoint of showing the progress achieved to date. The inheritance of some of the characters listed is somewhat more complicated, however, than would appear from the table, but lack of space prevents other than a very brief discussion of a few of the characters studied.

The white plumage of the White Leghorn is almost completely dominant to colored plumage, so that when a White Leghorn of either sex is mated to a colored bird of the opposite sex, the adult progeny have white plumage except that some individuals may have flecks of black in a few of the feathers. If the colored female is a Rhode Island Red, the male progeny usually have red on the shoulders, and some of the female progeny may have red on the neck and breasts. The dominance of the white plumage of the White Leghorn is due to the presence of a gene that prevents color from being expressed; otherwise the F_1's or crossbreds would be barred, for they also carry genes for barring, color, and the extension of black pigment.

The blue plumage of the Blue Andalusian is due to the presence of a gene that partially inhibits the development or expression of black pigment. Blue Andalusians are heterozygous for the gene; splashed white Andalusians are homozygous for the gene; black Andalusians are homozygous for the gene recessive to the inhibitor.

Barring in Barred Plymouth Rocks is due to a sex-linked gene which restricts the black pigment in the plumage to bars. The white bars, which alternate with the black ones, are due to the presence of the gene for silver, which is also sex-linked. The Barred Plymouth Rock male is, of course, homozygous for both genes, whereas the female is hemizygous, since she has but one gene for barring and one for silver. The gene for barring apparently has a cumulative effect because the white bars in the male tend to be approximately twice as wide as the black bars. But since the standard adopted for the Barred Plymouth male requires that the white and black bars be of approximately equal width, it is obvious that in the standard female the black bars will tend to be somewhat wider than the white bars.

Although the mode of inheritance of over 40 characters has been determined, a great deal of work has been carried on with other characters, and from time to time the dominance and recessiveness of some of them will undoubtedly be established. With some characters, how-

TABLE 12. SOME DOMINANT AND RECESSIVE CHARACTERS IN CHICKENS

Characteristic	Dominant or recessive	Autosomal or sex-linked
White plumage	In White Leghorns, almost completely dominant to color	Autosomal
White plumage	In White Dorkings, Langshans, Minorcas, Plymouth Rocks, Wyandottes, recessive to color	Autosomal
Black plumage	Dominant to recessive white	Autosomal
Blue plumage	Due to heterozygous condition of color genes	Autosomal
Silver plumage	"Silver" in Columbian, Silver-laced and Silver-penciled varieties dominant to "gold" in Red, Buff, Golden-laced and Golden-penciled varieties	Sex-linked
Barred plumage	In Plymouth Rocks, dominant to nonbarring	Sex-linked
Barred plumage	In Campines, dominant to nonbarring	Autosomal
White skin and shank color	Dominant to yellow skin and shank color	Autosomal
Dark skin and shank color	Recessive to nondark skin and shank color	Sex-linked
Rose comb	Dominant to single comb	Autosomal
Pea comb	Dominant to single comb	Autosomal
Walnut comb	Dominant to rose, pea, and single	Autosomal
Crest	Dominant to absence of crest	Autosomal
Muff and beard	Dominant to absence of muff and beard	Autosomal
Naked neck	Dominant to normal neck feathering	Autosomal
Feathered shanks	Dominant to nonfeathered shanks	Autosomal
Vulture hock	Recessive to normal hock	Autosomal
Long tail	Incompletely dominant to normal tail	Autosomal
Frizzle plumage	Incompletely dominant to normal plumage	Autosomal
Silkie plumage	Recessive to normal plumage	Autosomal
"Frayed" feathers	Recessive to normal feather development	Autosomal
Close feathering	Dominant to loose feathering	Autosomal
Late feathering	Dominant to early feathering	Sex-linked
Slow feathering	Recessive to fast feathering	Autosomal
Flightless	Dominant to normal wing	Autosomal
Rumplessness	Dominant to normal condition	Autosomal
Dwarfism	Recessive to normal	Autosomal
Creeper condition	Dominant to normal condition, lethal when homozygous	Autosomal
Hereditary blindness	Recessive to normal sight	Autosomal
Polydactyly	Dominant to four-toed condition	Autosomal
Early sexual maturity	Dominant to late sexual maturity	Autosomal and sex-linked
Broodiness	Dominant to nonbroodiness	Autosomal and sex-linked

ever, progress in determining their Mendelian inheritance will probably be slow because of the fact that there are in each case many genes involved and there are, in addition, such complicating factors as the influence of environment, hormones, and management practices on the expression of the character whose inheritance is being studied. The hatchability of eggs, the growth of chicks, the viability or livability of chicks, resistance to disease, egg production, and flesh production are characters of such fundamental importance that knowledge concerning methods of controlling their inheritance should be of vital concern to poultry breeders.

PRINCIPLES IN CONTROLLING INHERITANCE

Most flock owners want to grow chickens that will give better returns in egg and meat production. Many others would also like their flocks to be more uniform in plumage color, as in the case of New Hampshires, Rhode Island Reds, and Barred Plymouth Rocks. Low mortality in growing stock and laying flocks, rapid growth, early feathering, superior breast fleshing, good egg size, shell texture, and interior quality, as well as high hatchability are other desirable characters in the strain of chickens kept.

Most flock owners purchase chicks, and even though many of them do not carry on an organized breeding program, they are interested in the kind of breeding program carried on by those from whom they purchase chicks. Students of poultry husbandry, therefore, are naturally interested in the principles involved in controlling inheritance to improve poultry.

Genetic Basis of Variability. No two birds are exactly alike, and no two males or no two females produce exactly the same kind of progeny. This is obvious when it is realized that when a pair of birds mate and produce offspring, each parent transmits to each of its offspring one gene or the other of each of its many pairs of genes. Thus the variability depends on the number of gene pairs for which the parents are heterozygous. Each offspring receives from each parent a sample half of its inheritance. Since the chicken has 38 pairs of autosomes and one or two sex chromosomes according to sex, each of which carries many genes, some probably up to 100 or more, the number of kinds of gametes that could be produced would be enormous. With probably thousands of different gametes produced, it is apparent that an enormous number of hereditary combinations is possible.

An examination of any flock of chickens will reveal a considerable degree of variability. There are differences in body size, length of shank and other body dimensions, shape of comb, pigmentation of the iris,

length of feathers arising from each feather tract, and in many other external characters. There are differences in rates of growth, fleshing ability, resistance to disease, semen production in males, egg production in females, and hundreds of other functional characters. Many flocks probably carry several lethal and sublethal genes, and many genes probably influence the production of hormones by the endocrine glands. Each characteristic is due either to one gene or several genes. The important point for the poultry breeder to keep in mind is that the unit of inheritance is the gene and not the character. Most parents are undoubtedly heterozygous for many pairs of genes.

Heredity and Environment. The amount of variability that exists in any flock of chickens is not due entirely to genetic variance. It is true, of course, that characters such as type of comb and color of eggshell are due to specific genes, and environment plays little or no part in the development of these characters.

With some characters, however, progress in determining their inheritance will probably be slow because of the fact that there are in each case many genes involved and there are, in addition, such complicating factors as the influence of environment, hormones, and management practices on the expression of the character whose inheritance is being studied. The hatchability of eggs, the growth of chicks, the viability or livability of chicks, resistance to disease, egg production, and flesh production are characters of such fundamental importance that knowledge concerning methods of controlling their inheritance should be of vital concern to poultry breeders.

The six characters of fundamental importance just mentioned are known as physiological characters because numerous vital processes that take place within the body of the chicken are involved in their development. That they are inherited there seems to be no question, but the genetic evidence to date indicates that most of the hereditary variations that exist with respect to each of the characters are caused by a large number of genes, each of which, for the most part, probably exercises a relatively small effect.

Moreover, environment frequently plays an important part in the full development of these characters; in fact, some characters, though gene controlled may not be expressed unless a suitable environment prevails. Two illustrations will serve to emphasize the relationship between heredity and environment in the development of physiological characters: (1) Although the genes for high hatchability may be present, hatching results may be very disappointing owing to faulty methods of incubation; (2) the genes for high egg production may be present, but egg production may be very low as a result of an improperly balanced diet or poor housing

conditions. Rarely do ideal conditions of environment prevail whereby the genes are allowed to give full expression to their potentialities.

The Possibilities of Selection. Since there is such variability among the members of any flock, the best that the poultry breeder can do is to decide which members of his flock will be selected to produce offspring and which of those selected shall have few or many offspring.

By selection is meant deciding which males and females are to be parents. What counts most in poultry improvement is the number and

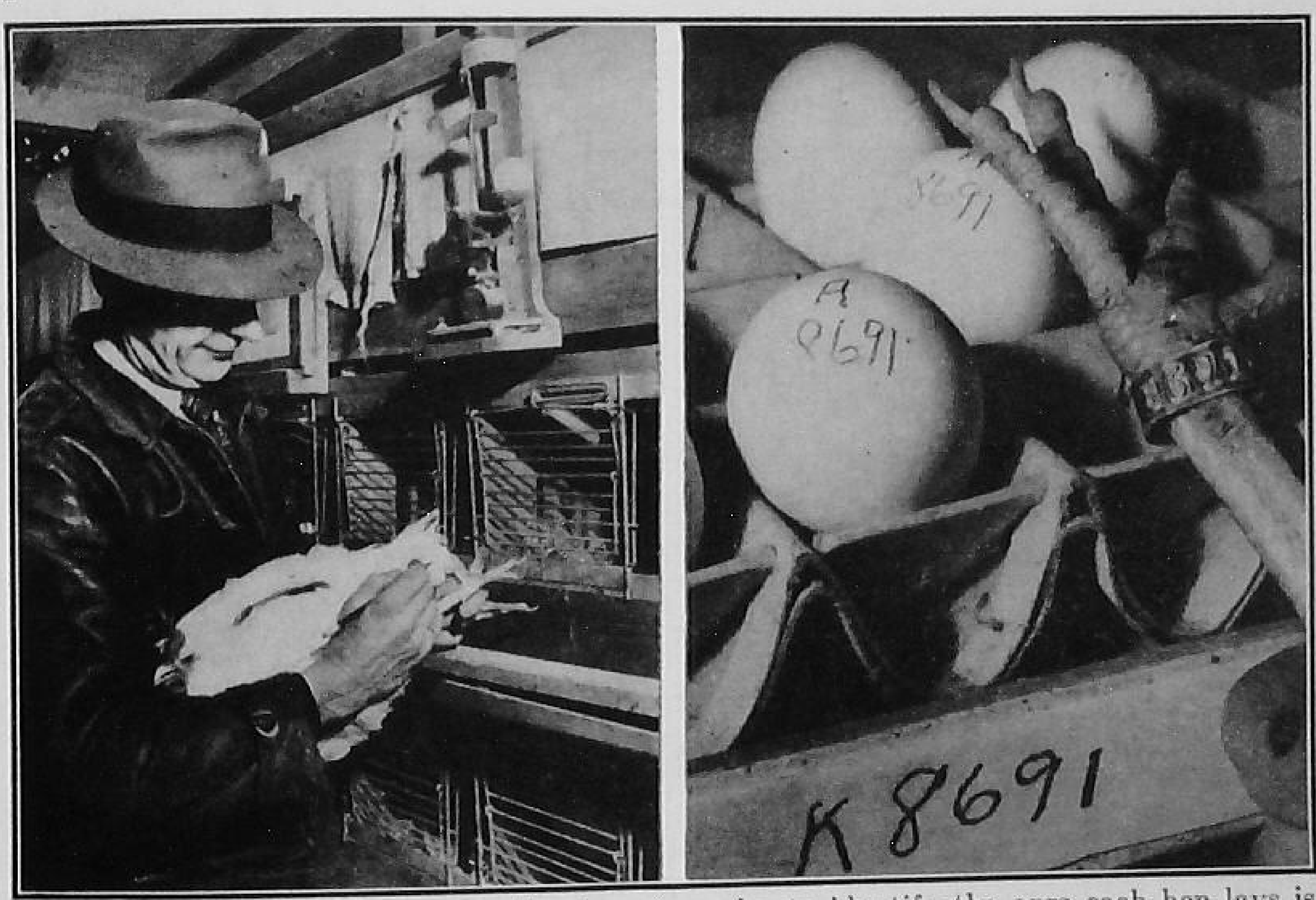


FIG. 54. Left, trap-nesting breeding hens in order to identify the eggs each hen lays is necessary to carry on a constructive breeding program. Weighing a certain number of eggs laid by each hen at certain times is advisable. Right, each egg laid by a hen is marked with her leg-band number and usually also by a letter to designate the sire to which she was mated. (*U.S. Dept. Agr.*)

quality of progeny raised and added to the breeding flock, because those not allowed to reproduce cannot affect the genetic constitution of future generations. Moreover, if the breeding worth of the progeny raised each year is not superior to the breeding worth of the parents, no progress is made.

The problem of the poultry breeder is to be able to identify which of the two parents is superior in its ability to transmit the desirable genes. It should be kept in mind, however, that selection can do nothing toward creating new genes. Nevertheless, the selection of the best individuals for future breeding purposes makes possible the segregation of desirable genes from each of the parents and the recombination of these desirable genes in the progeny.

One of the inherent difficulties involved in poultry-breeding practice is that the poultry breeder usually considers several different characters simultaneously when making his selections. What he should keep in mind is that the larger the number of characters on which selection is based, the lower the intensity of selection for each of the characters that he is endeavoring to improve by selection. In other words, the more attention paid to unimportant characters the less valuable is the selection for the economically more important characters.

Random Matings. In many farm flocks, including those used for producing eggs for hatcheries, the males and females used for breeding

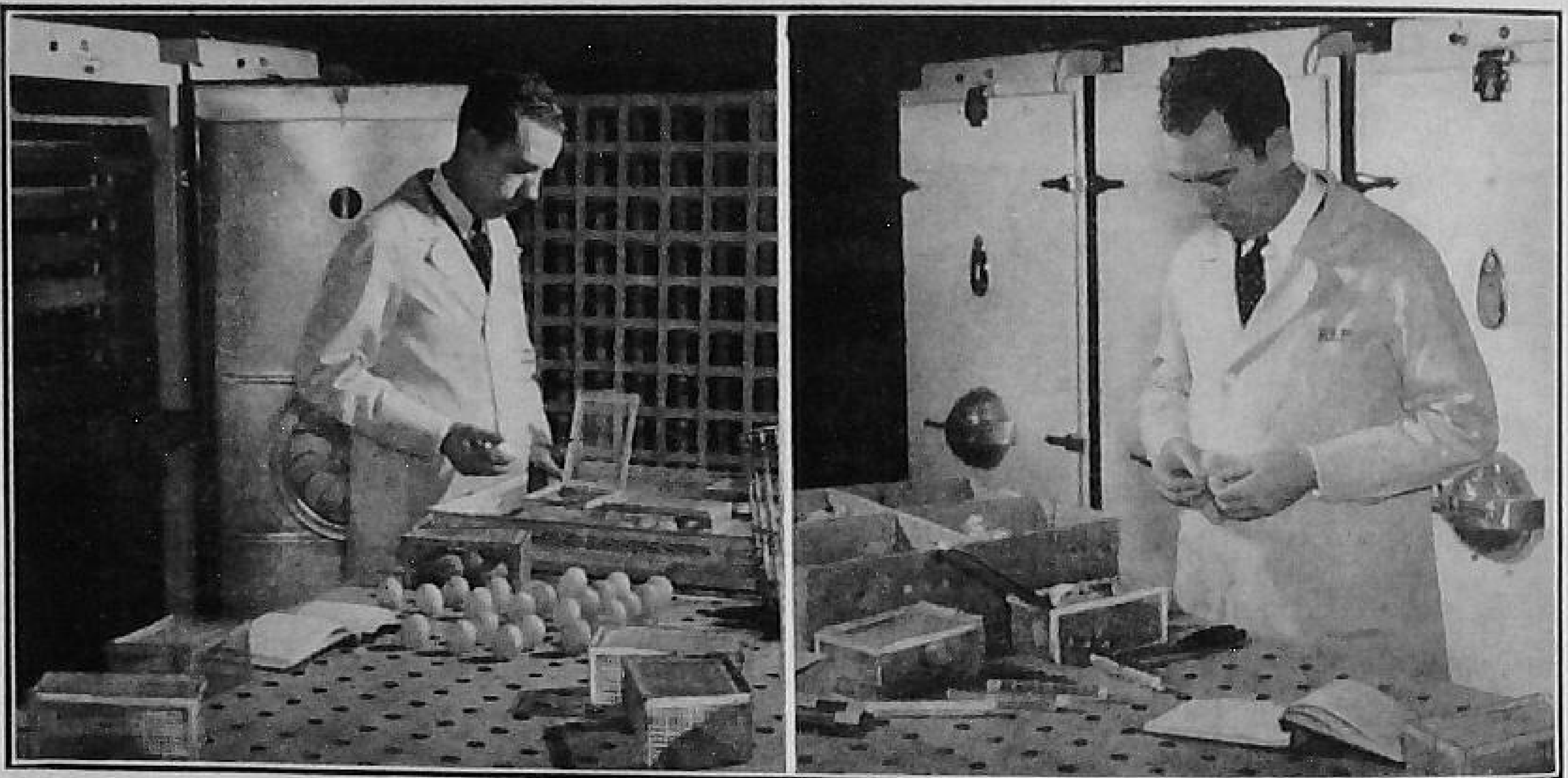


Fig. 55. Left, placing the eggs laid by each hen in a separate hatching basket at the time the eggs are transferred to the hatching compartment in order to be able to identify the sire and dam of each chick hatched. Right, banding the chicks hatched in each hatching basket and recording each chick's wing-band number under the number of the sire and dam from which it was secured.

purposes are chosen at random, except for varying intensities of selection based on body type and physical characters. Since all the males are allowed to intermingle with all the females, random mating takes place between males and females. With this system of mating, improvement of the genetic constitution of the generations produced from year to year depends on the effectiveness of the selection of breeders.

Outbreeding. This system of breeding has been practiced by many flock owners for many years, especially by those who exhibit standard-bred poultry at poultry shows. The practice consists of purchasing one or more male birds from another breeder of the same breed or variety with the hope of improving the quality of progeny secured from the matings. During recent years the same practice has been followed by many flock owners interested in improving their flocks with respect to

egg production, fleshing, or other characters. In outbreeding, the males and females are less closely related to each other than in the case of random matings.

The principal effect of outbreeding is to increase the heterozygosity of the progeny. Therefore, the breeding value of the outbred progeny is lowered.

Crossbreeding. Crossbreeding is the mating of birds belonging to different breeds or varieties, so that the natural result is to combine many different genes from rather widely separated sources. Since the characters in each of the purebred parents are due, for the most part, to the effects of dominant genes, it is obvious that the progeny of a crossbred mating contains many dominant genes in a heterozygous condition, some of the dominant genes having been received from one purebred parent and some from the other. Many dominant genes produce more favorable effects than do recessive genes, so that progeny produced by crossbreeding is usually superior in many characters over either of the parental breeds crossed. This superiority is said to be due to heterosis. The results secured from crossbreeding depend to a considerable extent, however, upon the qualities possessed by the parental breeds that are crossed.

Crossbreeding has been practiced extensively in the United States for the production of chicks for broiler raisers.

Naturally, crossbreeding tends to lower the breeding value of the crossbred progeny by making the progeny more heterozygous and by making selection among the progeny less effective. When crossbreds are mated together, their progeny is usually more variable than the crossbreds produced by the original crossing of two breeds.

Inbreeding. In practice, this system of breeding consists of mating birds that are more closely related among themselves than are the members of the flock to which they originally belonged. From the practical standpoint, inbreeding is understood to mean the mating of relatively closely related individuals, such as cousins, half brother and sister, full brother and sister, and parent to offspring. From the standpoint of the effects of inbreeding, it is a matter of convenience to poultry breeders to consider three forms of inbreeding: (1) mild inbreeding, such as the mating of first cousins; (2) close inbreeding, such as the mating of a parent to its offspring or mating a full brother to his full sisters; (3) intensive inbreeding, close inbreeding carried on for several successive generations.

The outstanding effect of inbreeding is to increase the chances of the progeny inheriting the same genes from the sire and the dam, the inbred progeny being homozygous for more genes than either parent. It should be kept in mind, however, that homozygosity of undesirable as well as

desirable genes tends to increase as the result of inbreeding. This is a blessing in disguise because it means that inbreeding provides the poultry breeder with a means of detecting the existence of undesirable genes in his strain. In many cases, because of the increase in homozygosity of undesirable genes, some of which may lower hatchability, retard growth, and decrease egg production, entire families are discarded. This means that an intensive breeding program is quite expensive to carry on and could hardly be carried on successfully by poultry breeders who maintain a limited number of breeding pens from year to year.

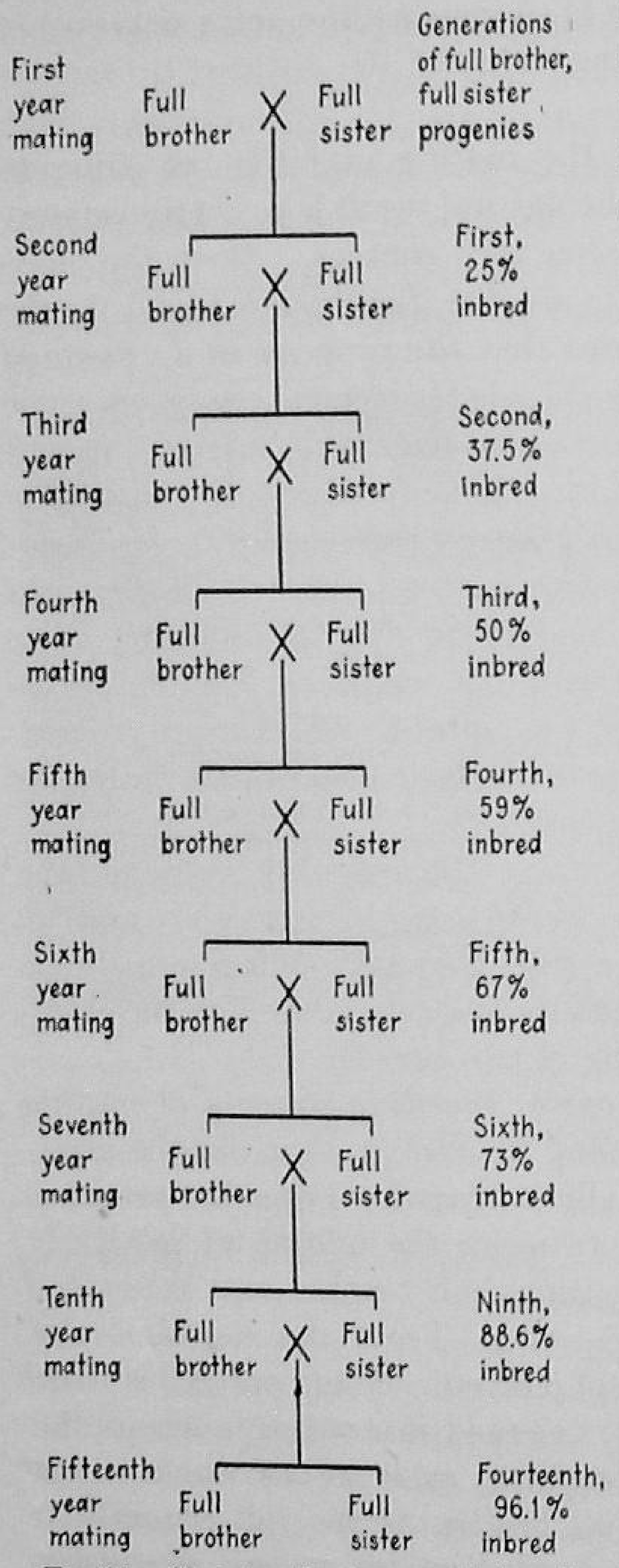


Fig 56. Showing the degree of inbreeding of the progenies of successive generations of full-brother × full-sister matings.

Producing Hybrid Chickens. One of the most recent developments in poultry breeding in the United States is the crossing of inbred families. Crossings are made between inbred families of the same variety and crossings between inbred families of different breeds. The principal objective in crossing inbred families has been to increase the average egg production of the progeny produced. In several instances the results secured have been quite promising.

Hybrid chickens are the progeny produced by crossing inbred lines of different breeds and varieties. An inbred line is one that has been developed by close inbreeding for successive generations to the extent that the mating of a male and female of the inbred line produces progeny whose amount of inbreeding exceeds that of the third-generation progeny produced by successive generations of full-brother × full-sister matings.

Figure 56 shows how an inbred line of any breed or variety could be developed. The third successive year of full-brother × full-sister

matings produce a third generation of inbred progeny that is 50 per cent inbred.

Figure 57 shows how different kinds of hybrid chicks may be produced. The varieties mentioned are used for purposes of illustration only; other breeds and varieties could be used.

Farmers naturally want to know the reason for this relatively high degree of inbreeding of purebreds before the inbred lines of different breeds or varieties are crossed to produce hybrid chicks. Egg produc-

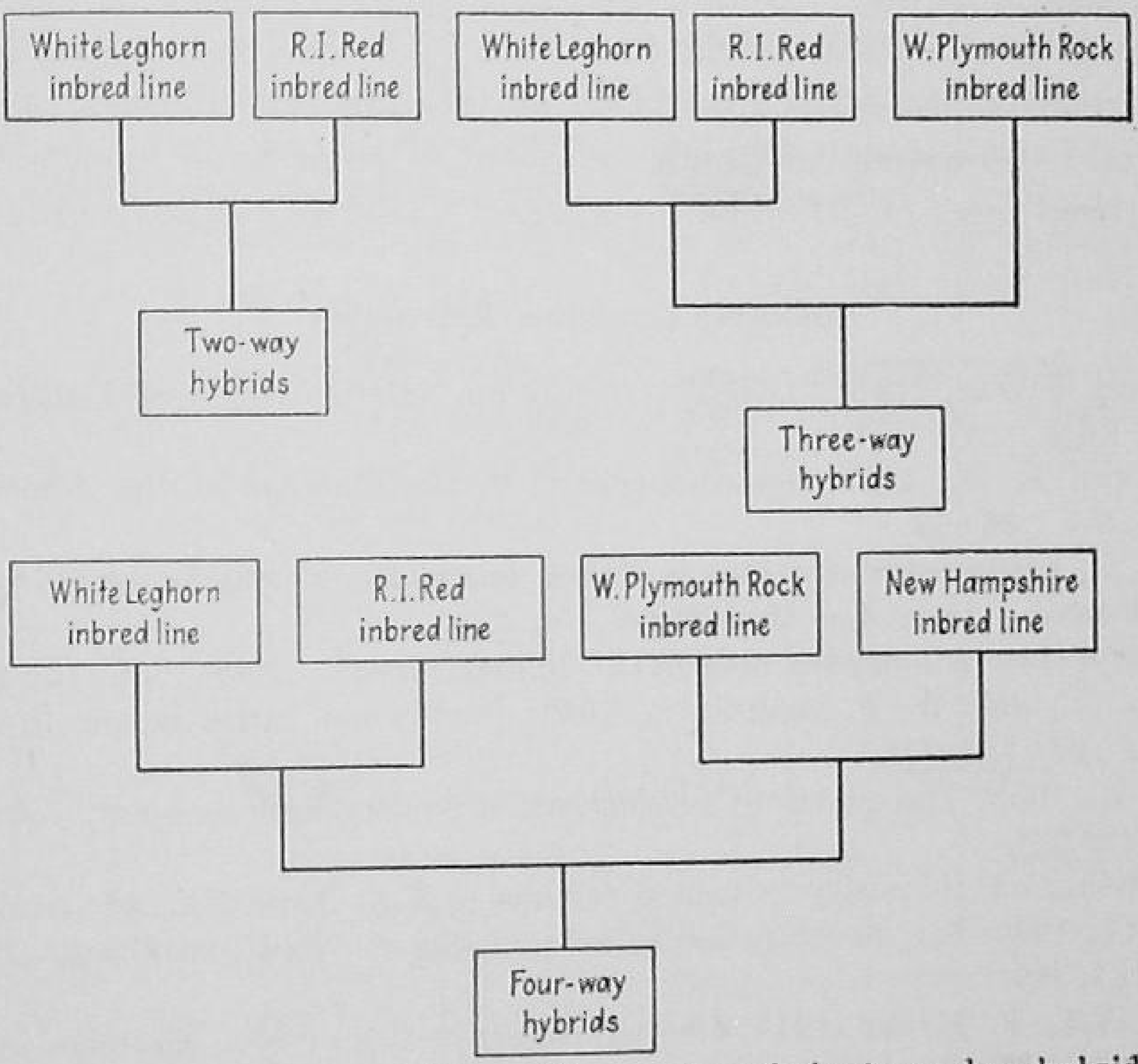


Fig. 57. Crossing inbred lines of different breeds or varieties to produce hybrid chickens. Another method of producing hybrids is first to cross two inbred lines of the same breed or variety and at the same time cross two inbred lines of another breed or variety and then cross the progenies secured from these two crosses.

tion is inherited, and many genes are involved. There are genes which have a good effect on egg production, such as those which induce pullets to start laying relatively early in life, and other genes which induce pullets to lay for a relatively long time, as in the case of late molters. But there are other genes which have a bad effect on egg production, such as those which keep pullets from starting to lay early in the fall when egg prices are high, and genes for broodiness which reduce egg production. In addition there are numerous other genes which have a deleterious effect on the hatchability of eggs and the growth of chicks.

Close inbreeding brings to light these undesirable genes because they

produce their effects in certain families produced by full-brother × full-sister matings. The hybrid-poultry breeder eliminates these families in his subsequent breeding program, selecting future breeding stock from superior families which possess the desirable genes for high egg production. It is an expensive procedure because so many families have to be eliminated. But the superior families that are kept for future breeding purposes are more uniform genetically than most families secured from progeny testing involving family selection when intensive inbreeding is not practiced.

The quality of hybrid chicks produced by hybridizers depends largely on the selection pressure applied in developing inbred lines of superior quality and the extent to which undesirable genes have been eliminated in the inbred lines of different breeds and varieties that are crossed.

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CHAPTER 5

BREEDING PRACTICE

In many flocks far too many birds of inferior breeding worth are used each year because many poultry breeders apparently have never adopted a logical basis on which to select their breeding stock. Mediocrity tends to reproduce itself. How to secure good fertility and how to select and mate males and females of superior breeding worth for the development of superior strains is related in the following pages.

SECURING GOOD FERTILITY

The poultry breeder should always keep in mind that the percentage of fertile eggs secured is the first factor in determining the number of chicks secured in proportion to the eggs set.

Management of Breeding Stock. The proper management of the breeding stock is important in order to secure maximum fertility. The poultry house should be kept reasonably dry.

Extremely cold weather is apt to cause a lowering in fertility, so that special precautions should be taken to keep the house comfortable when the temperature drops suddenly. To avoid the danger of having combs badly frozen, some poultry breeders cut off the combs of the males, this practice being called "dubbing." Sharp scissors may be used to decomb baby chicks, and scissors or tinners' clippers may be used to decomb older birds. The operation should be performed only on a warm day; otherwise, excessive bleeding may occur. After the comb has been amputated, a clean feather may be laid on, or a little flour may be sprinkled over the cut surface. In the case of cutting off the wattles, it is a good practice first to apply a clamp to each wattle, and then after the wattles are amputated apply an astringent, such as tincture of ferric chloride, before releasing the clamps. Dubbing does not affect semen production.

In addition to temperatures much below freezing, temperatures above 100°F. also tend to lower fertility. Properly insulated and well-ventilated poultry houses should be a help in maintaining good fertility during the warmer seasons of the year.

Poorly fed birds tend to give lower fertility than well-fed birds. This is particularly important in the case of males because many of them are inclined to eat too little when running with females. This can be cor-

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Extremely cold weather is apt to cause a lowering in fertility, so that special precautions should be taken to keep the house comfortable when the temperature drops suddenly. To avoid the danger of having combs badly frozen, some poultry breeders cut off the combs of the males, this practice being called "dubbing." Sharp scissors may be used to decomb baby chicks, and scissors or tinners' clippers may be used to decomb older birds. The operation should be performed only on a warm day; otherwise, excessive bleeding may occur. After the comb has been amputated, a clean feather may be laid on, or a little flour may be sprinkled over the cut surface. In the case of cutting off the wattles, it is a good practice first to apply a clamp to each wattle, and then after the wattles are amputated apply an astringent, such as tincture of ferric chloride, before releasing the clamps. Dubbing does not affect semen production.

In addition to temperatures much below freezing, temperatures above 100°F. also tend to lower fertility. Properly insulated and well-ventilated poultry houses should be a help in maintaining good fertility during the warmer seasons of the year.

Poorly fed birds tend to give lower fertility than well-fed birds. This is particularly important in the case of males because many of them are inclined to eat too little when running with females. This can be cor-

males as possible with different females, the males might be shifted to other pens about halfway through the breeding season. When a shift is made, at least 10 days must elapse in saving hatching eggs between the time the first male was taken out and the second male put in to be reasonably sure of the sire of each chick hatched.

Stud Matings. When a male bird is confined to a coop or breeding pen and each female, upon being released from the trap nest, is placed with him for mating, the practice is called "stud mating." This method of mating is seldom practiced by poultry breeders, apparently because of the time and labor involved. On the other hand, by this method it is possible to mate one male to many females.

Artificial Insemination. This method involves the stimulation of the male bird so that he produces semen, which is collected in a container and then a quantity of the semen is deposited in the oviduct of a female. By this method a large number of females may be inseminated with the semen of one male. Doses of 0.1 cc. of semen once each week for each female have been reported to give good fertility. Best results are secured if insemination is done soon after the bird has laid. Poor fertility is apt to result from inseminating females during the morning because the uterus is liable to contain a fully formed egg. Artificial insemination is sometimes practiced by poultrymen who keep layers in cages.

Egg Production and Fertility. Very poor layers are apt to give lower fertility than good layers. In one case it was observed that hens laying 4 or more eggs per clutch gave better fertility than hens laying 1 to 3 eggs per clutch. The reason apparently is that in flock and pen matings when the rate of ovulation is low the females are inclined to copulate less frequently than when the rate of ovulation is high.

Good Fertility in 10 Days. In flock and pen matings it is possible to secure a fertile egg approximately 24 hr. after copulation takes place, but a high percentage of fertile eggs is not likely to be obtained within 5 to 7 days after making up a mating. In order to secure maximum fertility before starting to save eggs, it is well to make up the matings at least 10 days in advance.

Good Fertility for 10 Days after Matings Discontinued. While it is possible to secure a fertile egg for as long as 31 days after copulation has taken place, the per cent of fertile eggs tends to decline about the fifth day and declines sharply following the tenth day after the males have been removed from the breeding pens.

BREEDING FOR HIGH HATCHABILITY

By hatchability is meant the ratio of the number of chicks that hatch to a given number of fertile eggs, when presumably ideal conditions of

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or below the mean of the group as a whole, and then comparing the average hatchability of the eggs of the daughters from each group of dams.

The data in Table 13 show that in the case of breed, the daughters of dams having high hatchability have higher hatchability than the daughters of dams having low hatchability.

Influence of Rate of Laying. The eggs of birds laying 4 or more eggs per clutch tend to hatch better than the eggs of birds laying fewer eggs per clutch. From various observations made on the relationship between

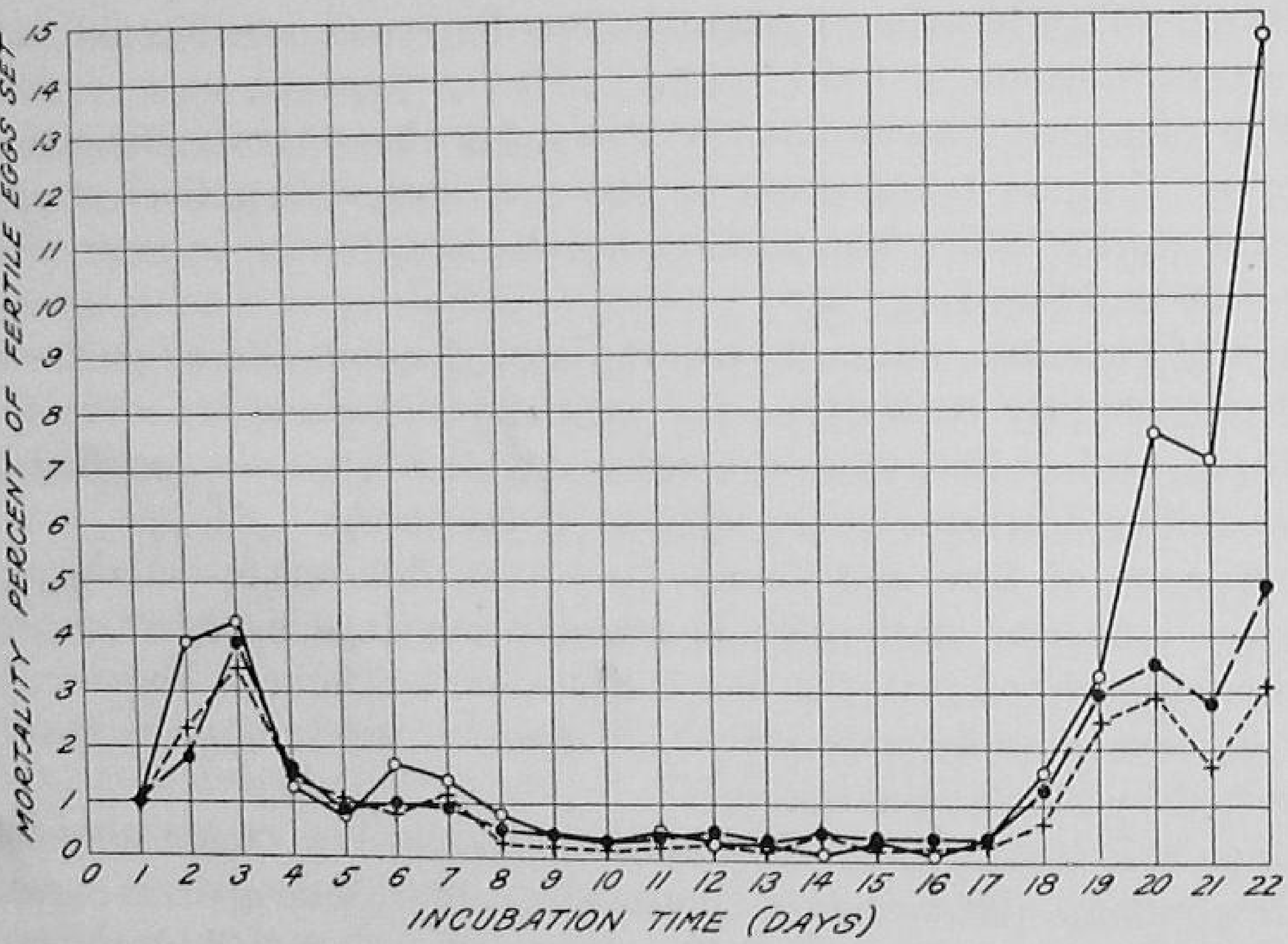

FIG. 58. Embryonic mortality in eggs secured from inbred matings, —O—, is usually higher than embryonic mortality in eggs secured from noninbred matings, —●—, especially during the first 3 and the last 3 days of incubation. Embryonic mortality in eggs secured from crossbred matings, —+—, is usually less than that from noninbred matings. (*Byerly, Knox, and Jull.*)

the egg production of dams during the breeding season and the hatchability of their eggs, it has been shown that the eggs of the best layers tend to hatch better than the eggs of the poorest layers.

Effects of Inbreeding and Crossbreeding. Close inbreeding, especially if practiced for a few years, tends to reduce the hatchability of the eggs of the inbred birds. The deleterious effects of close inbreeding are due largely to increased embryo mortality during the first 4 and especially the last 3 days of incubation, as illustrated in Fig. 58. At the same time, if rigid selection of future breeding birds is based on the hatchability of their dams' eggs, it is possible to maintain relatively high hatchability in inbred matings. Mating highly inbred males to noninbred females

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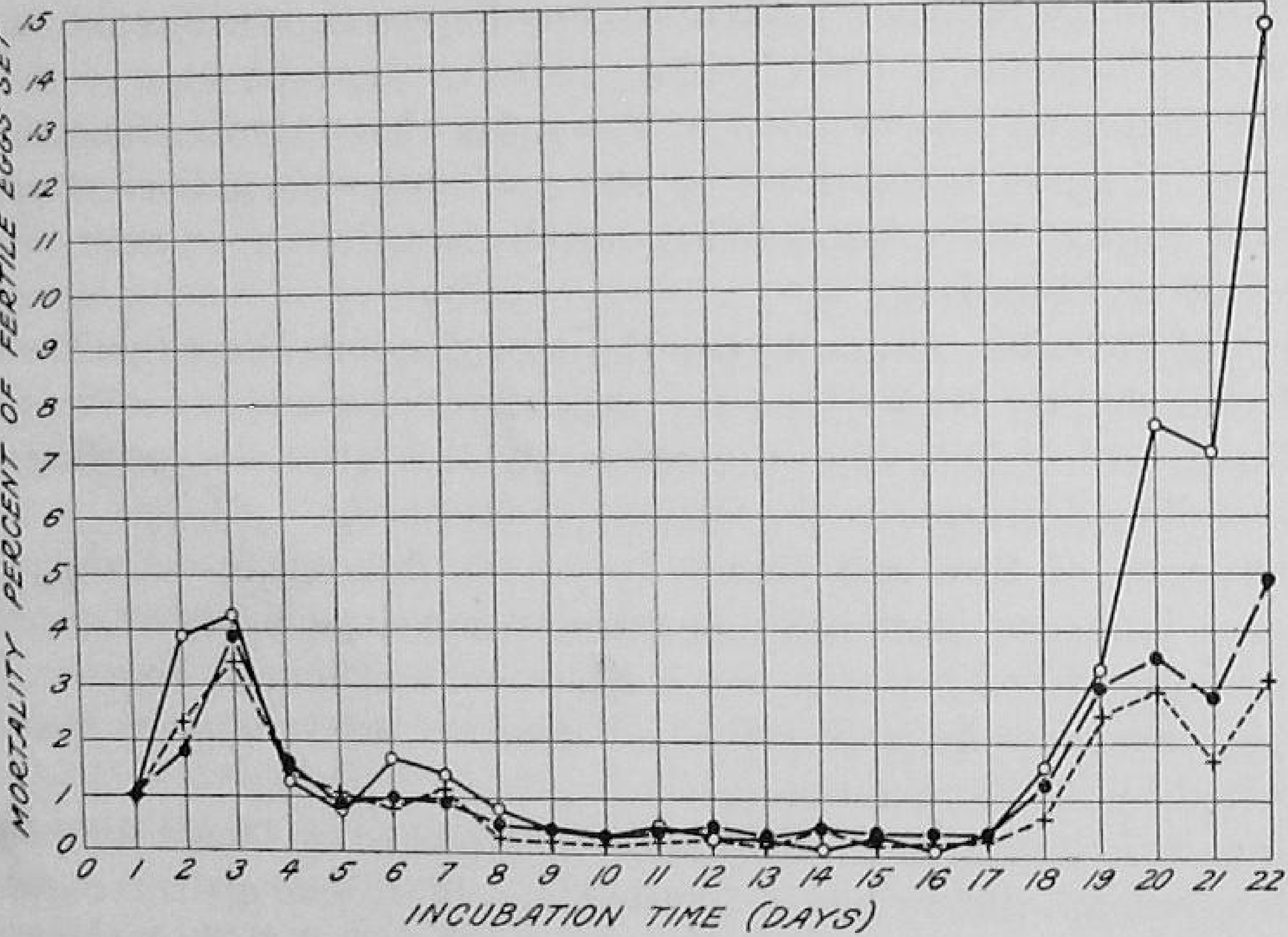

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birds would continue to harbor the infective agent and thus be a means of spreading the disease.

Breed and Strain Differences in Disease Resistance. Observations have been made at various times showing that there are certain differences between breeds in their physiological response to unfavorable conditions. White Leghorns are much more resistant to the fatal effects of extremely high temperatures than Barred Plymouth Rocks and Rhode Island Reds. On the other hand, an instance has been reported in which Barred Plymouth Rocks, White Plymouth Rocks, and Rhode Island Reds were much more resistant to infestation by the large roundworm, *Ascaridia lineata*, than White Leghorns and White Minorcas.

Within a breed there are sometimes strain differences with respect to disease resistance. In one case, it was shown that strains of the same variety differed with respect to their resistance to pullorum disease. Selected strains consistently maintained relative resistance through successive generations. At the same time, it is obvious that pullorum-testing work for the purpose of eliminating from breeding flocks all birds which harbor the organism that causes the disease must be carried on for the simple reason that it has not been established that it is possible to develop strains of chickens completely resistant to pullorum disease.

On the other hand, considerable progress has been made at some of the state agricultural experiment stations in developing strains relatively resistant to fowl paralysis (a general term used by poultrymen to include leucosis, lymphocytosis, neurolymphomatosis, tumors, and related conditions). If sufficient numbers of highly resistant strains are developed in the future, the distribution of cockerels from these strains among hatchery flocks producing eggs for hatcheries might lead to a general lowering of losses from this very costly disease. Data are given in Table 14 indicating marked differences in level of mortality from neoplasms, of which between 90 and 95 per cent were cases of lymphomatosis, between the daughters of sires belonging to the resistant and the daughters of sires belonging to the susceptible line. Data are also given pertaining to the level of mortality from all causes, including neoplasms.

The data in Table 14 show that the levels of mortality from neoplasms and from all causes were lower, for the most part, among the daughters of sires in the resistant lines than among the daughters of sires in the susceptible line. It has been shown by lines of work that strains of birds that are more resistant to the leucosis complex than other strains are also inclined to be more resistant to other diseases.

The possibility of developing strains relatively high in viability is shown by the data given in Table 15. In 1937 and 1938 several matings of White Leghorns were made for the purpose of determining any family

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The data in Table 15 show that in each year the viability of the progeny of the high-viability matings was higher than that of the progeny of the low-viability matings. In 1940 and 1941 the differences were significant.

Effects of Inbreeding and Crossbreeding. The effects of inbreeding on viability of growing chickens and laying pullets depend upon the quality of the strains used and the intensity of inbreeding. Poor-quality strains, lacking inherent vigor, usually produce progeny with relatively low viability when the strains are closely inbred and especially if they are intensely inbred. On the other hand, results have been secured in some cases in which the viability of the progeny was not reduced materially as the result of inbreeding, especially in those cases in which the progeny test was applied each year in the selection of breeding stock.

Crossbreeding, in general, tends to increase the viability of the crossbred progeny over that of the purebred progenies of the parental breeds. However, pure breeds in which the viability of their purebred progenies is high could not be expected to produce crossbred progeny with much higher viability. On the other hand, pure breeds whose purebred progenies are low would be expected to produce crossbred progeny with higher viability, as a result of the bringing together in the crossbred progeny of the favorable dominant genes from each of the purebred strains. The results given in Table 16 show what might normally be expected as the result of crossbreeding, the results being expressed in terms of mortality.

TABLE 16. MORTALITY AMONG PUREBRED AND CROSSBRED PROGENIES TO 12 WEEKS OF AGE
(W. R. Horlacher, R. M. Smith, and W. H. Wiley, 1941)

Kind of progeny	No. of birds	Mortality, per cent
Purebred Rhode Island Reds	244	5.74
Purebred White Wyandottes	190	15.26
Crossbreds from White Wyandotte ♂[a] × Rhode Island Red ♀♀[a]	66	6.06
Purebred Barred Plymouth Rocks	152	12.50
Purebred White Plymouth Rocks	189	15.87
Crossbreds from White Plymouth Rock ♂ × Black Plymouth Rock ♀♀	184	4.35

[a] ♂ = male; ♀ = female.

The foregoing discussion on breeding for high viability makes it clear that resistance to disease is inherited, and that by developing a sound selection and breeding program based on progeny testing, it should be possible to develop strains relatively resistant to disease.

BREEDING FOR EARLY FEATHERING

The rate at which growing chickens become fully feathered over all parts of the body has assumed increasing importance in the case of broiler and fryer production. Birds that are poorly feathered over the back at marketing time often have numerous pinfeathers showing after the birds are plucked. This is objectionable and often leads to a discount in price when the birds are sold, especially when dark pinfeathers are evident.

Sometimes poor feathering in growing chickens is due to overcrowding or faulty diets or both. Excessively high brooder temperatures and excessively low humidity in the brooder house often result in poor feathering. In the majority of cases, however, poor feathering is due to heredity.

Leghorn chickens usually feather out earlier than most chickens of the general-purpose breeds, such as Plymouth Rocks, New Hampshires, and Rhode Island Reds. Some strains of the general-purpose breeds have been developed, however, that feather out as early as Leghorns. It is always possible to distinguish cockerels and pullets secured from an early feathering general-purpose strain from cockerels and pullets secured from a late-feathering general-purpose strain. Production-bred strains of general-purpose breeds are much more apt to be early feathering than exhibition-bred strains of these breeds.

Determining Rate of Feathering. Three methods are employed to determine rate of feathering: (1) the length of the primary wing feathers and the relative length of the coverts of the day-old chick; (2) the number of secondary wing feathers at hatching time; (3) the relative length of tail feathers at about 10 days of age.

At hatching time Leghorn chicks usually have considerably longer primaries and secondaries than most general-purpose chicks. This is especially true with respect to the primaries. Most Leghorn chicks have more secondaries showing at hatching time than most chicks of the general-purpose breeds. The chicks should be examined as soon as possible after hatching by looking at the primaries and secondaries from the underside of the wing.

Length of Primaries and Coverts. Although the length of the primaries at hatching time is of some importance in distinguishing early-feathering from late-feathering chicks, another factor should be considered. Growing alongside each primary feather is a covert, each primary feather and covert being enclosed in a sheath. In early-feathering chicks the covert is about two-thirds as long as and more slender than the primary feather, whereas in late-feathering chicks the covert is about

the same length as the primary feather, which is almost as slender as the covert.

Number of Secondaries. The number of fairly well-developed secondaries visible at hatching time is much more important in denoting early feathering than is the length of the primaries and primary coverts. There should be at least seven well-developed secondaries to denote early feathering (see Fig. 59). Certain strains of Leghorns and of early-feathering general-purpose varieties produce chicks which may have a reduced number of secondary wing feathers at hatching time. This

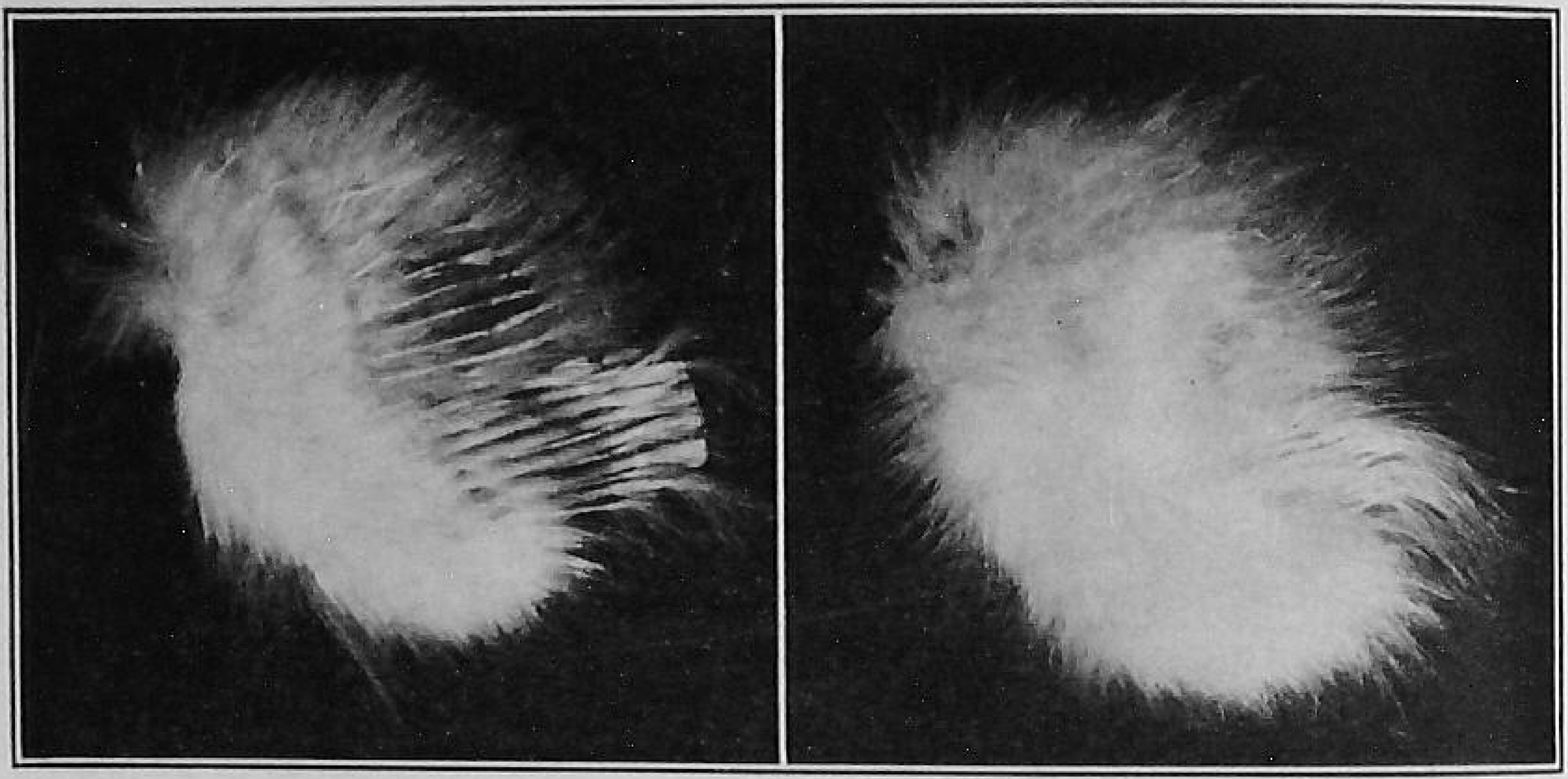


FIG. 59. Left, early-feathering wing of a New Hampshire chick at hatching time; note particularly the eight well-developed secondaries and that the primary coverts are about two-thirds as long as the primaries. Right, late-feathering wing of a New Hampshire at hatching time; note absence of secondaries and relatively poor development of primaries. (*C. S. Williams and M. A. Jull*, 1943.)

circumstance retards tail feathering at 10 days of age but apparently does not affect feathering over other parts of the body after the first 6 weeks.

Ten-day Tail Feathering. At 10 days of age early-feathering cockerels and pullets have tail feathers about ½ in. in length, whereas late-feathering cockerels and pullets have practically no tails.

Complete feathering over the back at about 8 weeks of age is very desirable, especially in the case of broilers and fryers. Chicks which are shown to be early feathering at hatching time by the length of the primaries and the relative length of their coverts and the number of secondaries and also at 10 days by the length of the tail feathers are much more apt to be well feathered over the back at 8 weeks of age than chicks which are shown to be late feathering at hatching time and again at 10 days of age. In some early-feathering general-purpose strains, the degree of feathering over the back varies considerably due to the fact

that other genes, in addition to the early-feathering gene, affect the degree of back feathering at 8 weeks of age. Early-feathering strains of all varieties usually have wider feathers over all parts of the body than late-feathering strains.

Developing Early-feathering General-purpose Strains. Since early feathering is so important in the case of chickens raised for meat production, it is important to develop early-feathering general-purpose strains. Early-feathering males and females mated together produce early-feathering progeny. If a flock owner finds no early-feathering chicks at hatching time, he should secure chicks from a breeder who has an early-feathering strain. If a flock owner finds early-feathering chicks of both sexes at hatching time, it is a relatively simple matter to develop an early-feathering strain.

Variability in Feathering Rate. While it is true that it is usually fairly simple to distinguish early from late feathering among chicks at hatching time, there is often some variability of early feathering, due to non-sex-linked recessive modifying genes that tend to suppress feathering. These are the genes that usually cause the "bare-back" condition in broilers at marketing time. Also, there is often some degree of variability of slow feathering, due to non-sex-linked dominant genes which tend to improve feathering among slow-feathering birds at broiler age.

BREEDING FOR RAPID GROWTH, GOOD BODY CONFORMATION, AND SUPERIOR FLESHING

Housewives who purchase broilers, fryers, roasters, and fowl have a marked preference for birds with well-fleshed breasts. Good body conformation in market chickens, with abundant development of breast muscles over a relatively long keel, provides a relatively high proportion of meat to bone. A group of birds uniform in body conformation and with superior fleshing should be able to qualify for the best market grade and should command the highest prevailing market price. Not only is the production of high-quality market chickens in the best interests of consumers, thus tending to increase consumer demand for chicken meat, but producers also benefit because it is usually more economical to raise birds of superior quality than those of inferior quality.

The need for developing superior meat-type strains of chickens is more important than most farmers and commercial poultrymen realize. Approximately 90 per cent of the cockerels and probably 20 per cent of the pullets raised on farms each year, and most of the layers culled, are sold for meat. In addition there are many poultry enterprises devoted exclusively to growing broilers and fryers, where practically the entire crop is sold for meat.

Rapid Growth. In the production of broilers, fryers, and roasters, rate of growth is probably the most important factor affecting economic returns. The rate of growth in chickens is affected by various factors, including the conditions under which they are reared, the diets they are fed, and the presence of disease. In addition, rate of growth is inherited.

The results of several lines of research show that the rate of growth of the shank (tarsometatarsus) is a good index of the rate of growth of the

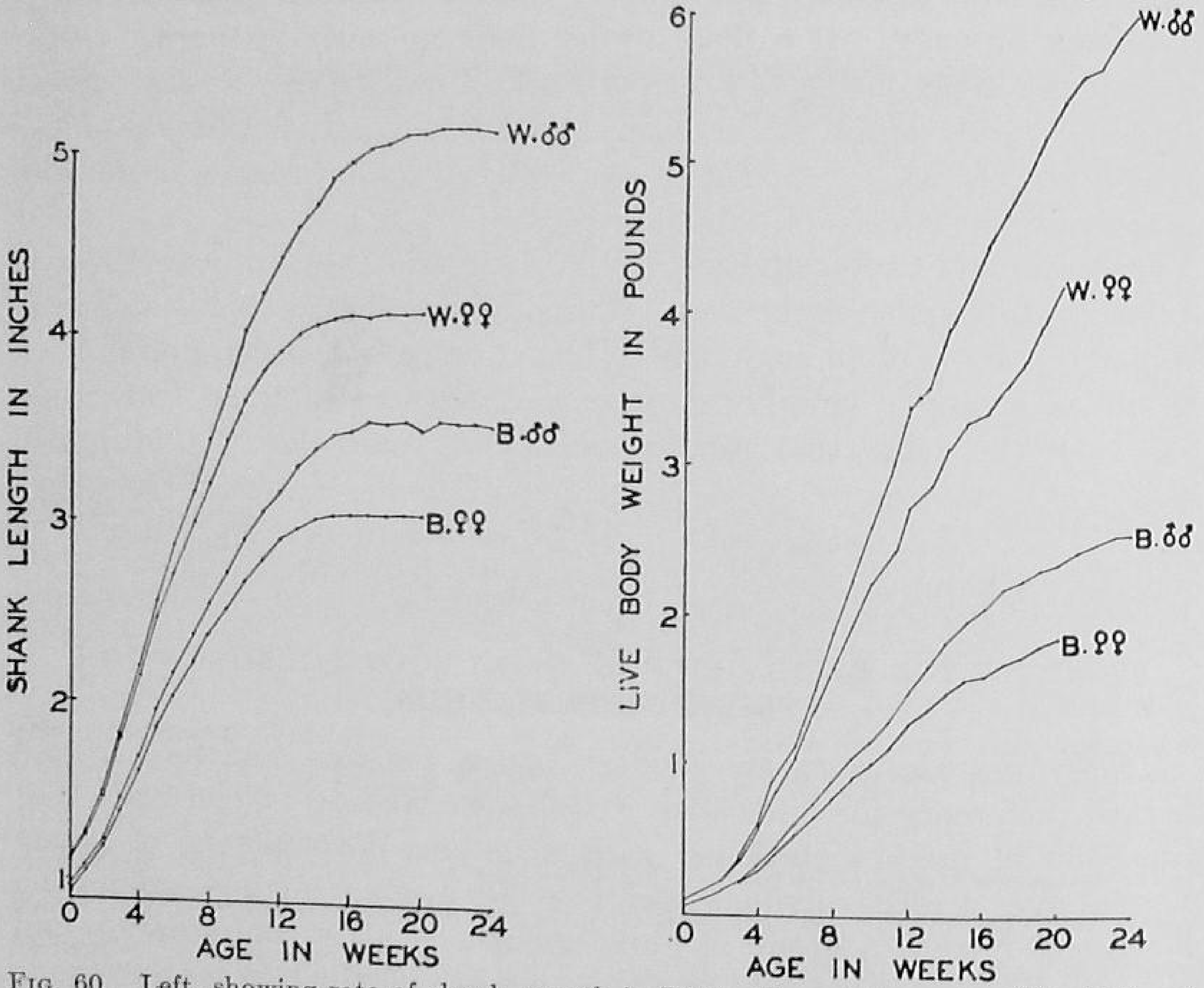


FIG. 60. Left, showing rate of shank growth in White Wyandotte males (W. ♂♂) and females (W. ♀♀), and Dark Cornish Bantam males (B. ♂♂) and females (B. ♀♀). Right, showing rate of body growth in the same birds. (*R. G. Jaap, R. Penquite, and R. B. Thompson*, 1943.)

body as a whole, under normal conditions. The rate of the growth of the shank and other long bones in birds is not nearly so variable as body weight. Relative to body weight, the rate of bone growth tends to increase from 4 to about 12 weeks and to decrease from about 12 to about 20 weeks of age. Males grow faster than females, and general-purpose breeders grow faster than Leghorns. In females the growth of the shank ceases at about 5 months and in males at about 6 months (see Fig. 60). Increase in body weight continues until about the end of the tenth month (see Fig. 60 for growth to 20 weeks in females and 24 weeks in males).

In any given strain of birds, the progeny of long-shanked parents tends to grow faster than the progeny of short-shanked parents (see data in Table 17).

In several strains of some of the general-purpose breeds it has been shown that rate of body growth is associated with rate of feathering. Early-feathering chicks tend to grow more rapidly than late-feathering chicks during the first few weeks (see data in Table 17).

TABLE 17. AVERAGE BODY WEIGHT IN POUNDS OF SHORT-SHANKED AND LONG-SHANKED NEW HAMPSHIRE PROGENIES, RESPECTIVELY, AT 10 WEEKS OF AGE IN RELATION TO RATE OF FEATHERING
(E. W. Glazener and M. A. Jull, 1946)

Strain	Rate of feathering	Males	Females
Short-shanked	Late	2.16	1.91
	Early	2.29	1.97
Long-shanked	Late	2.37	1.98
	Early	2.55	2.13

Variability in rate of body growth tends to increase from hatching time to about 4 to 6 weeks of age and then decreases at about the same rate to about 10 weeks of age, after which it decreases more slowly until the birds reach maturity. Therefore, the first step in the selection of future breeding stock from among the growing chickens should be undertaken when the chickens are about 5 weeks of age. The heaviest cockerels and pullets should be selected and toe-punched or wing-banded. If any of the birds are to be sold as broilers or fryers, another selection based on body weights should be made at selling time. At both times, pedigree-poultry breeders should determine the average weights of families of full brothers and of full sisters in order to determine from which families future breeders should be saved.

Good Body Conformation. When selection for rate of growth is made at about 12 to 14 weeks of age, before any birds are marketed, the birds should be examined for body shape. Those with broad and fairly deep bodies and relatively long, straight keels should be saved as breeders. The keel should be approximately parallel to the back and, above all, should be straight. Particular attention should be paid to the body conformation of cockerels, because each cockerel used as a breeder has about ten times as many progeny as any female to which he is mated. When the entire flock of cockerels and pullets is raised up to the fall of the year, selection for body conformation should be made at the time the pullets are put in the laying house. The annual selection of the very best cock-

erels and the best pullets on the basis of body conformation should do much to improve uniformity in this character in the progeny raised each year. The pedigree-poultry breeder has an advantage over the farm-poultry raiser and commercial poultryman because the pedigree breeder is able to select his birds on a family basis. His particular advantage is in being able to select outstanding cockerels from superior families.

Superior Fleshing. Before any birds in the flock are to be marketed, all of them should be examined carefully for fleshing, especially over the breast and legs. These parts constitute about 45 per cent of the dressed

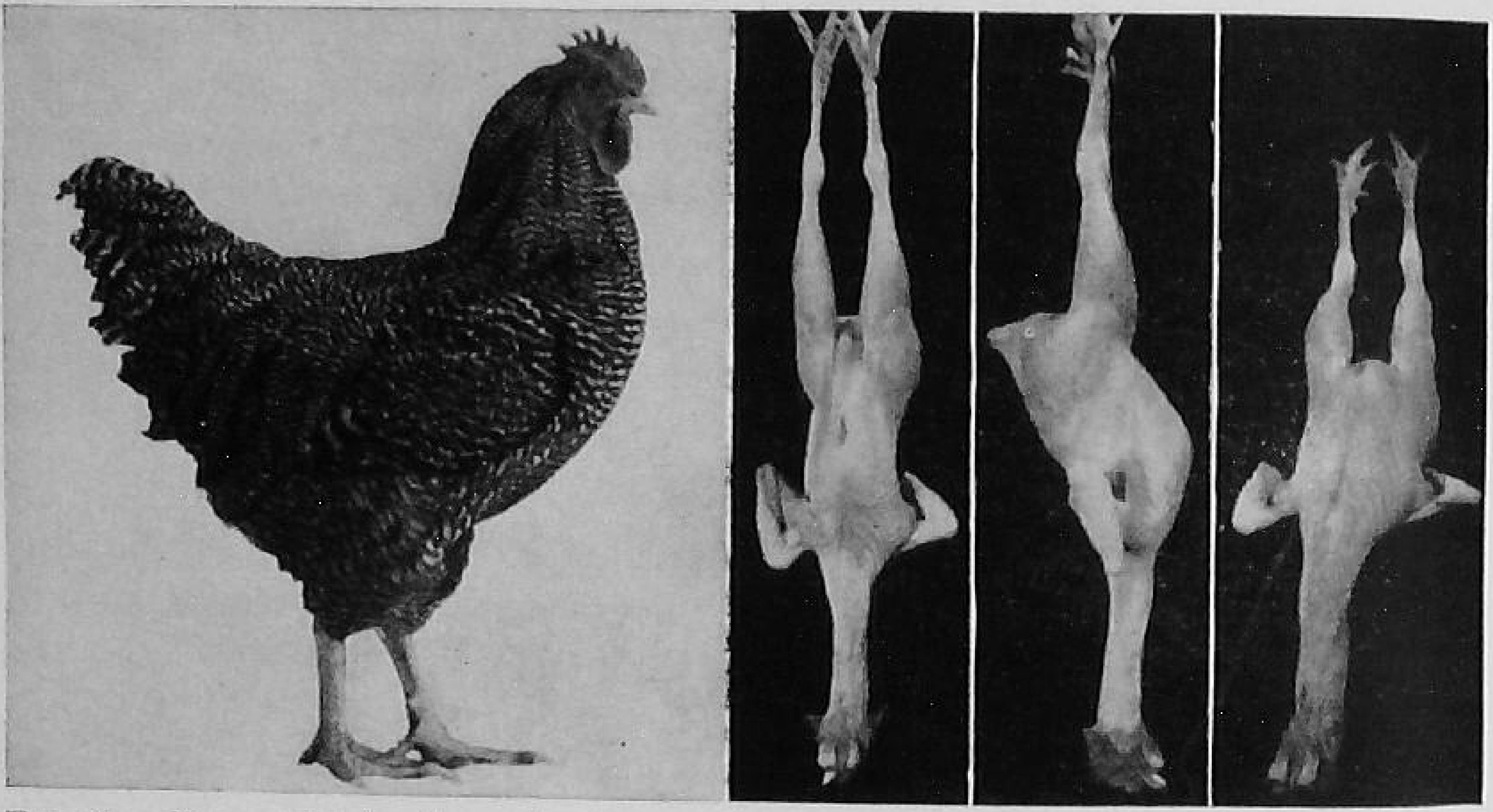


FIG. 61. Dressed birds of superior type and finish can be secured only from birds of the proper type and possessing good fleshing qualities. This Barred Plymouth Rock cockerel is shown alive at 26 weeks of age together with three views of him dressed. (*W. A. Maw.*)

weight of 3-lb. fryers. Dressed birds with well-rounded breasts are preferred by consumers.

The degree of fleshing over the breasts is influenced by diet and management during the growing season, but fleshing ability is inherited. Birds that have been fed the same kind of diet and managed in the same way nearly always show considerable variability in fleshing, especially if the breeding program has not included selection for fleshing ability.

Since fleshing ability is inherited, it is important for the flock owner to keep for breeding purposes the best fleshed birds. Grading the birds, especially the cockerels, into A, B, and C grades at selection time would be helpful (see Fig. 62).

At housing time it would be highly desirable to have two houses available for the pullets, one for grade A pullets and the other for grade B pullets. The very best of the grade A cockerels should be mated to grade A pullets. This mating should be the source of chicks to replace the

laying flock. Progeny testing for fleshing ability is the pedigree-poultry breeder's best chance for improving this character in his strain.

Efficient Utilization of Feed. In normal times, the cost of feed represents about one-half of the total cost of raising broilers, fryers, and roasters. When feed prices are high, the cost of feed increases relatively more than the other costs of production. It is highly important, therefore, that growing chickens gain rapidly in weight for the feed consumed. Rate of growth is the most important factor affecting efficiency of feed utilization. Generally speaking, the longer the time required for a growing chicken to attain a given weight, the lower the efficiency of feed utilization. Males are more efficient in utilizing feed than females. Strains of the same breed often differ markedly in efficiency. Results secured from one experiment showed that among birds attaining about

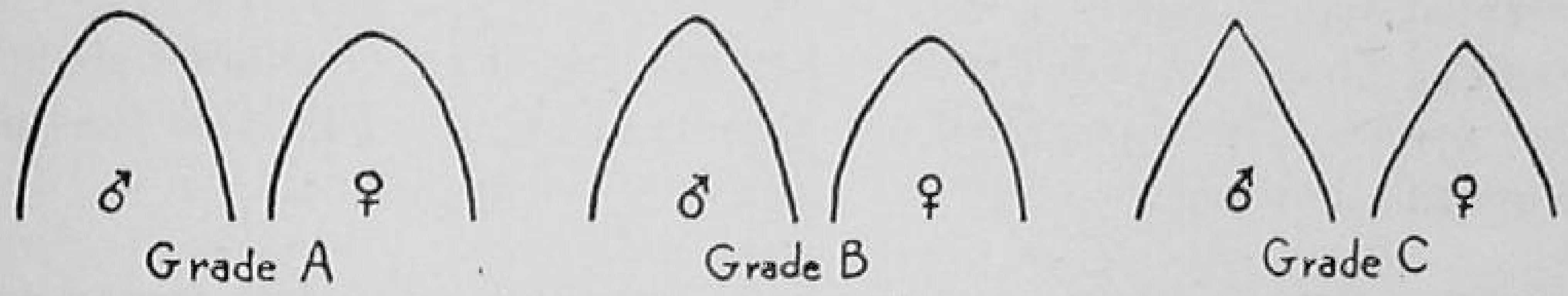


FIG. 62. Chart for grading male and female chickens for fleshing over the breast during the growing season. For each grade, the breast of the male is shown at the left and the breast of the female at the right. As chickens reach maturity, the breasts naturally tend to become plumper. (*C. S. Williams and M. A. Jull*, 1943.)

3.9 lb., fast-growing males required about 14.0 per cent less feed than slow-growing males. Developing strains of birds highly efficient in feed utilization would mean a tremendous saving in feed costs.

Effects of Inbreeding and Crossbreeding. Very little research has been carried on to determine the effects of inbreeding on growth rate or other characters associated with superior quality in market poultry. On the other hand, several experiments have been conducted to determine the effects of crossbreeding on growth rate and efficiency of feed utilization. Also, crossbreeding is practiced extensively for the production of chicks raised for meat production. In the Delmarva Peninsula, the most highly concentrated broiler-producing area in the United States, a popular cross used extensively has been Barred Plymouth Rock males of fast-growing strains mated to New Hampshire females of fast-growing strains.

When two breeds are crossed, their crossbred progeny usually grow faster during the first few weeks than the purebred progeny secured from the same purebred female parents mated to purebred males of the same breed in each case. The stimulation of growth in the crossbred progeny is said to be due to heterosis and is probably accounted for by desirable genes for rate of growth in the purebred parents of each breed being brought together in the crossbred progeny.

Table 18. Crossbred Progeny Secured from Matings of Barred Plymouth Rock Males and New Hampshire Females Grew Faster and Utilized Feed More Efficiently than Purebred Barred Plymouth Rock Progeny
(R. F. Poffenberger and S. H. DeVault)

	Purebred progeny	Crossbred progeny
Age marketed, weeks	13.7	12.6
Average weight per bird, lb	2.45	2.84
Average amount of feed per bird, lb	10.04	10.87
Average amount of feed per pound gain, lb	4.10	3.83

The data in Table 18 show that although the crossbred progeny were marketed approximately 1 week earlier than the purebred progeny, the crossbred progeny weighed more at marketing time, consumed slightly more pounds of feed per bird, but consumed about ¼ lb. less feed per pound gain in weight.

Table 19. Average Weight per Bird at 12 Weeks of Age and Average Amount of Feed Consumed per Pound Gain, Purebred and Crossbred Progenies
(W. R. Horlacher, R. M. Smith, and W. H. Wiley, 1941)

	Average weight per bird, pounds	Average No. of pounds feed per pound gain
Purebred Rhode Island Reds	2.20	4.48
Purebred White Wyandottes	2.48	4.44
Crossbreds from White Wyandotte ♂[a] × Rhode Island Red ♀♀[a]	2.76	3.99
Purebred Barred Plymouth Rocks	2.17	4.64
Purebred White Plymouth Rocks	2.27	4.53
Crossbreds from White Plymouth Rock ♂ × Barred Plymouth Rock ♀♀	2.38	3.99
Purebred White Wyandottes	2.53	4.30
Purebred White Plymouth Rocks	2.27	4.53
Crossbreds from White Wyandotte ♂ × White Plymouth Rock ♀♀	2.43	4.23
Purebred Rhode Island Reds	2.15	4.36
Purebred White Wyandottes	2.52	4.41
Crossbreds from Rhode Island Red ♂ × White Wyandotte ♀♀	2.27	4.37

[a] ♂ = male; ♀ = female.

The data in Table 19 show that sometimes crossbred progeny does not grow faster during the first few weeks than the purebred progeny of both parental breeds.

The data in Table 19 are in agreement with results secured by commercial-broiler producers, since experience has shown that the quality of crossbred progeny is determined largely by the quality of the parental breeds crossed.

Considerable improvement in the quality of broilers, fryers, and roasters can be achieved by carrying on a program of selecting breeding stock each year on the progeny-test basis. In closing this discussion on breeding for more efficient meat production and superior fleshing, it should be pointed out that all strains of breeders used should also be bred for high egg production. Flock owners who produce eggs from which chicks are secured for meat production are interested in keeping good laying strains in order to secure a profitable income.

BREEDING FOR HIGH EGG PRODUCTION

Except for certain specialized broiler-producing areas in the United States, the production of eggs has been the factor of greatest economic importance in poultry raising as far as the chicken industry is concerned. For the most part, therefore, the problem of the poultry breeder has been how to develop efficient egg-laying strains, at the same time giving due consideration to the economic importance of meat production. The greatest efficiency in egg production can be developed only in a flock that is bred for the various egg-production characters and where selection is carried on to eliminate the poor breeders.

The fact that many strains of modern breeds lay an average of 180 or more eggs per bird during the first laying year as compared with an average of probably 12 or 15 eggs per bird by the ancestors of modern stocks indicates that egg production is inherited. Too much must not be taken for granted, however, for the simple reason that much of the improvement in egg production that has taken place over a long period of years is due to the results of domestication and better methods of management, including the feeding of better balanced diets. Nevertheless, it has been well established that egg production is inherited, although the mode of inheritance has yet to be determined.

Economic Importance of High Production. All flock owners are naturally interested in producing eggs as economically as possible. Few flock owners realize, however, the relative importance of good egg production in reducing the total costs of production. The cost of feed is the most important item of expense in producing eggs; in normal times it

amounts to about 50 per cent of the total costs, and during times of high feed prices it may amount to as much as 65 per cent of the total costs.

The feed consumed by layers is used for maintenance and for egg production. The maintenance requirements include the feed used for the production of energy, whereby the layer is able to maintain normal body temperature in cold weather and carry on the various processes involved in breathing, digestion, tissue repair, and daily activities. The largest portion of the feed consumed by layers is used for maintenance. The balance is used for egg production. The higher the egg production, the greater is the proportion of feed used for egg production rather than for

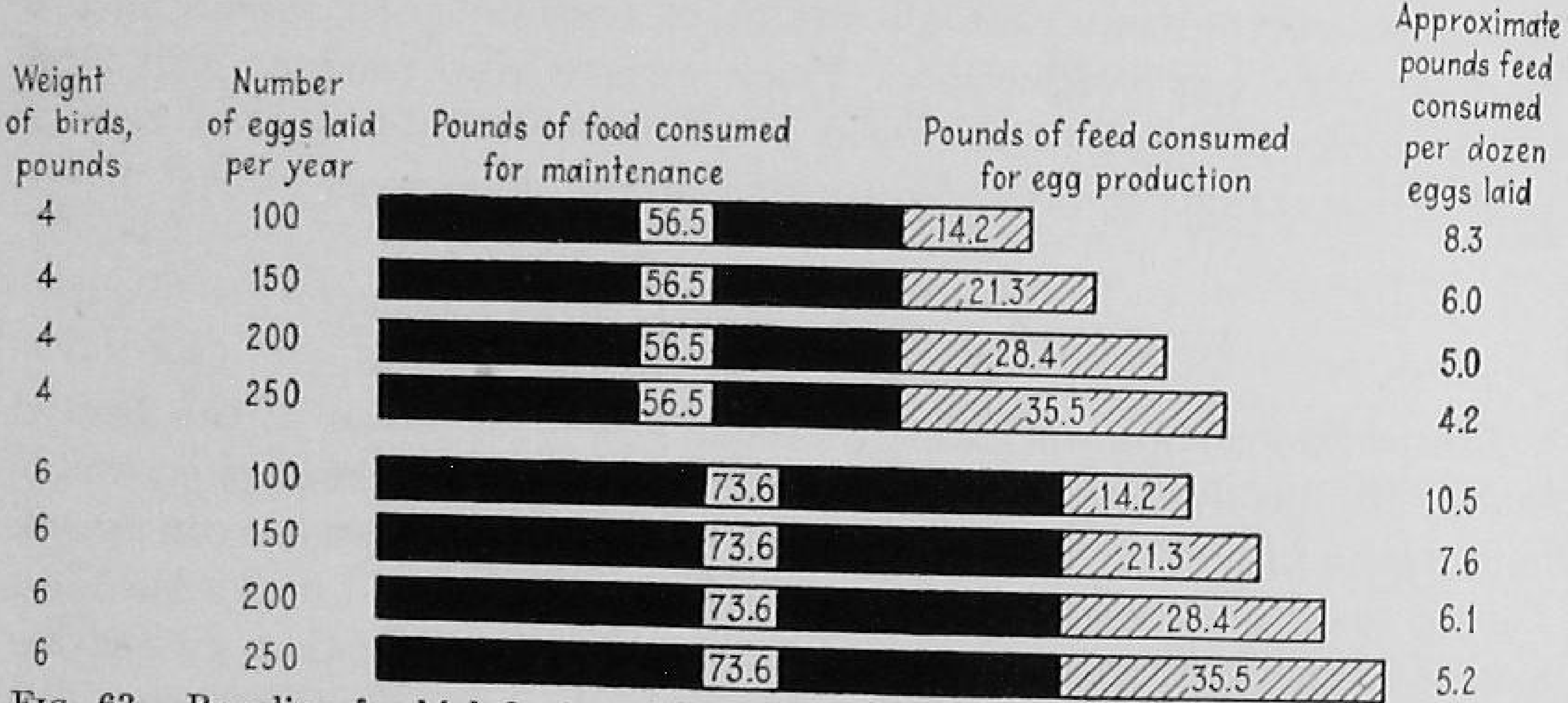


FIG. 63. Breeding for high laying ability is very necessary in order to enable birds to utilize feed efficiently in producing eggs.

maintenance; but the larger the bird, the greater is the proportion of feed used for maintenance. In the case of layers of all sizes, as egg production increases, relatively fewer pounds of feed are used per dozen eggs produced. This is the outstanding reason why breeding for high egg production is so important. Since body size and egg production are heritable characters, it is obvious that efficiency of feed utilization in producing eggs is a breeding problem.

One of the first steps in a program of breeding for high egg production is the selection of the prospective breeders. Most pedigree-poultry breeders examine their layers carefully before deciding which to save and which to cull. There are certain physical characters which can be used to distinguish birds which are in laying condition from those which are not laying. In addition, there are certain physiological changes that take place in relation to egg production that make it possible to distinguish the best layers from the poorest ones, if observations are made at sufficient intervals. Although the selection of prospective breeders on the

basis of physical appearance and physiological changes serves the purpose of saving the best birds for future breeding purpose, there is no assurance of their breeding worth until further tests are made. Hatchery-flock owners and commercial-market-egg producers also use the method of identifying the best layers in order to cull the uneconomical producers at different times during the laying year. In this case, however, the principal object is to maintain egg production at an economical level. Poorly bred flocks need to be culled more rigidly than well-bred flocks in order to maintain an efficient level of egg production throughout the year.

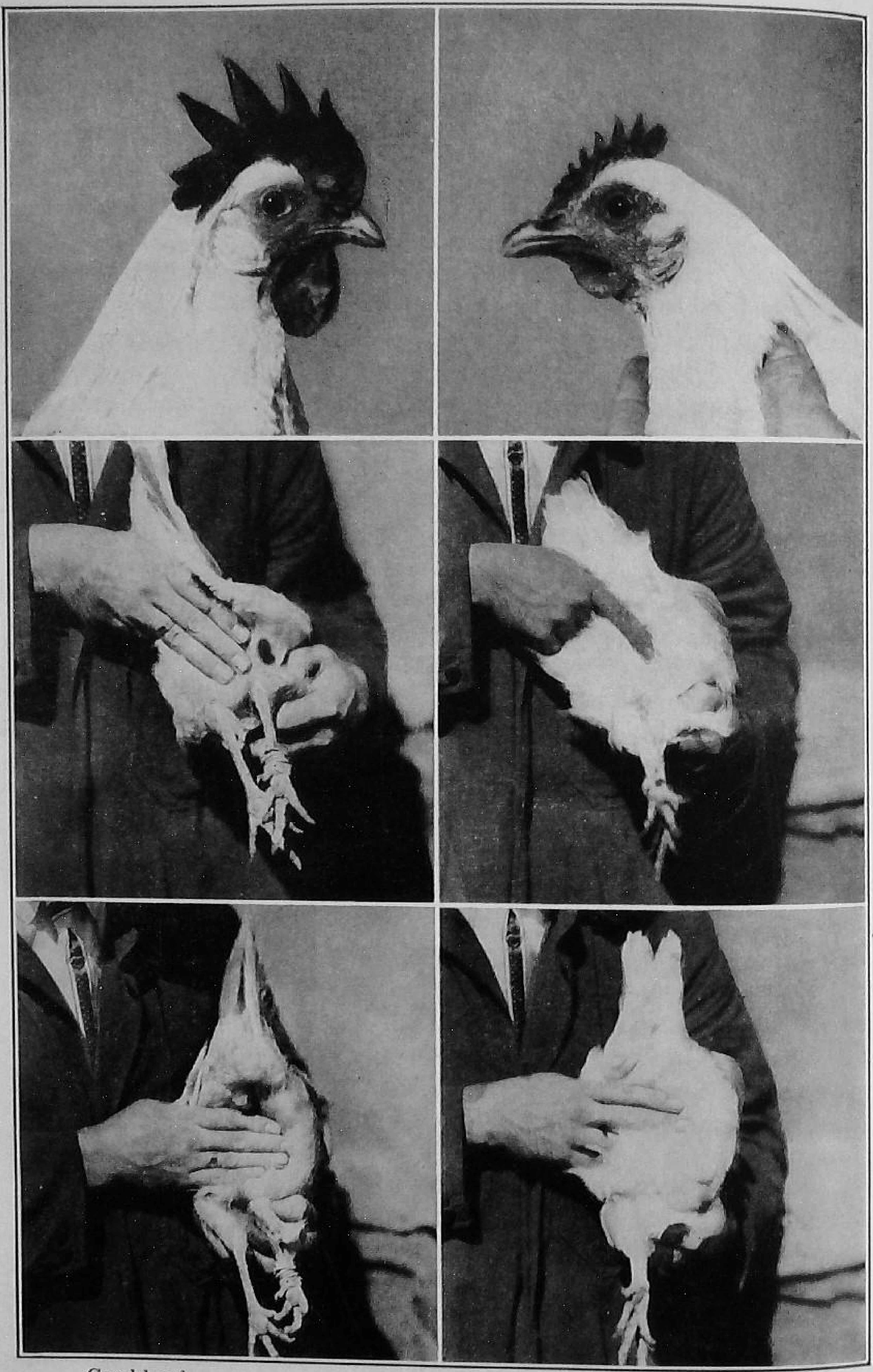
Selection on Basis of Physical Appearance. There are certain physical characters the appearance of which indicates whether or not a bird is in laying condition. If the comb and wattles are fully developed, bright red, and waxy in appearance, the bird is probably laying heavily; but if they are cold, dried, and shrunken, the bird is not laying. The small, round vent of the pullet becomes enlarged, oval in shape, and moist when the bird is in active laying condition. The pubic bones, two small bones at the sides of the vent, become spread apart when the bird is in laying condition, and continuous production causes them to become thin and pliable. The abdomen, which contains most of the digestive and reproductive organs, should be of good size, and the skin covering the abdomen should be soft and pliable, in contrast to the thick and coarse skin often observed in poor layers.

Neither the shape of the head nor the shape of the body is a reliable indication of laying ability, although birds with extremely narrow or very coarse and beefy types of heads and bodies are usually poor layers.

Bright, prominent eyes, with no irregularity of pupils are desirable characteristics of good layers.

Depigmentation of Beak and Shanks. In all newly housed pullets of yellow-skinned breeds there is usually an abundance of yellow pigment in the beak, shanks, toes, vent, and eye ring and in the white of the ear lobe of breeds having normally white ear lobes. The yellow pigment comes from the feed which the birds eat. When a pullet starts to lay, the yellow pigment of the feed is diverted to the yolks of the eggs instead of going to the beak, shanks, and other parts noted previously. As long as egg production continues, these parts gradually lose their pigment, so that they become bleached in appearance. The longer a bird continues to lay, the greater the degree of bleaching. The yellow pigment does not return to the beak, shanks, and other parts until production ceases.

The order in which the pigment disappears from the different parts is as follows: (1) from the vent; (2) from the eye ring, which is formed by the inner edges of the eyelid; (3) from the ear lobes of breeds having white ear lobes, such as Leghorns; (4) from the beak, beginning at the base and



Good head
Good width between pubic bones
Good body capacity

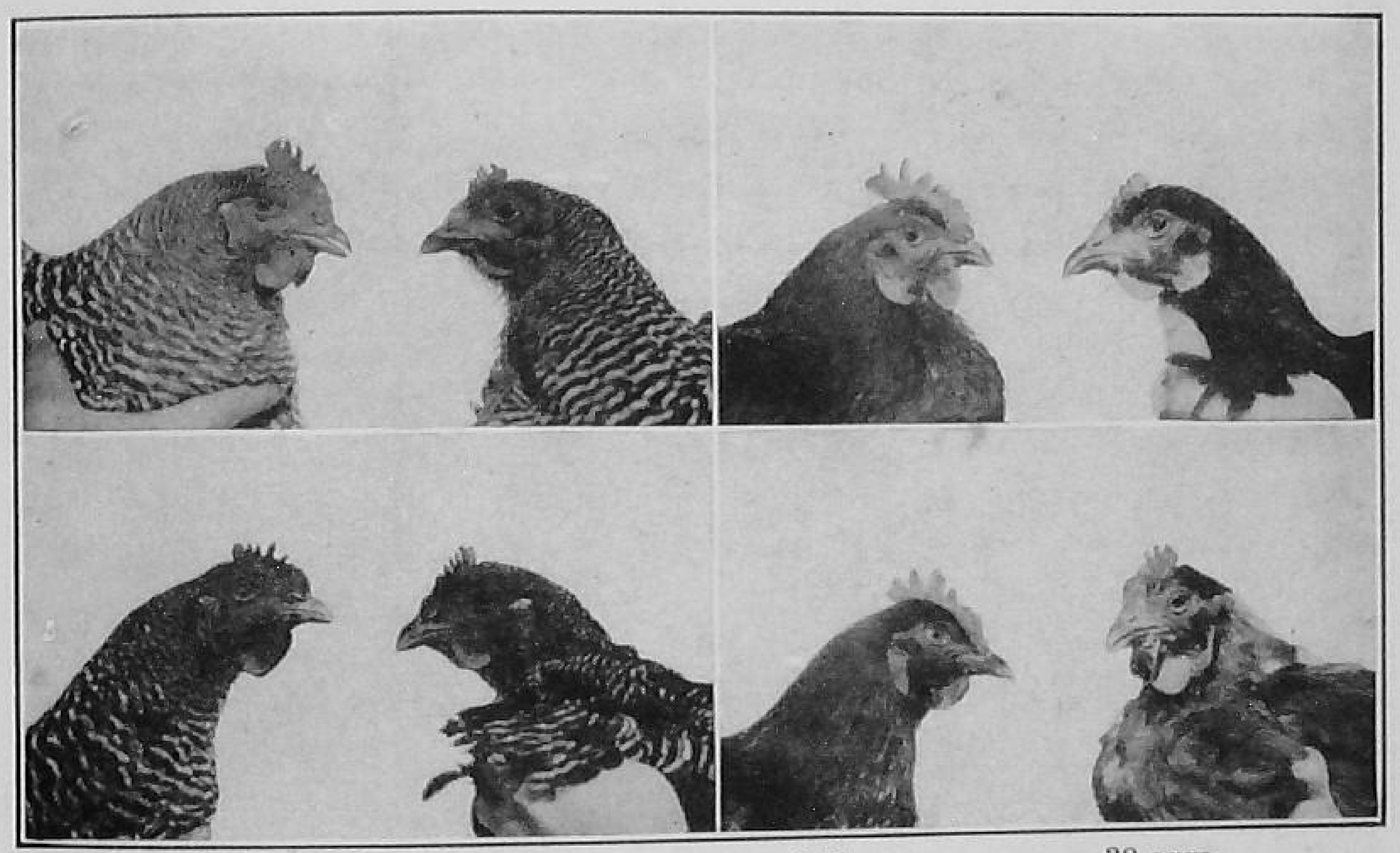
Poor head
Poor width between pubic bones
Poor body capacity

Fig. 64. Three important steps in judging hens for laying ability and body capacity. (*Ralston Purina Mills.*)

extending toward the tip; (5) from the shanks, disappearing first from the front of the shank and later from the rear.

Under average conditions, a completely bleached beak indicates that the hen has been laying for 4 to 6 weeks, whereas completely bleached shanks indicate that the hen has been laying for 20 to 24 weeks.

Time and Duration of Molt. Under normal conditions the average laying bird usually undergoes her first complete annual molt at the conclusion of her first year of laying. The time and duration of the first annual molt are important points in distinguishing between poor and



| 204 eggs | 60 eggs | 205 eggs | 30 eggs |
| 288 eggs | 81 eggs | 263 eggs | 155 eggs |

FIG. 65. The shape of the head is not an indication of laying ability, except that the "beefy" type indicates a poor producer and an extremely narrow head is undesirable. (*U.S. Dept. Agr.*)

good layers. Birds that molt early are usually the poorest layers. The bird that is a poor layer usually stops laying in July or August and takes a relatively long time to complete her molt. These early molters are often out of production about 4 months and usually do not start their second laying year until December or January. Many late molters, however, after a rest of about 2 months, also begin to lay in January (see Table 20).

Some very high-producing hens take a rest period of only 4 to 5 weeks. Hens of this type usually begin to lay again before the new plumage is fully grown out. Some hens lay part way through the molt. When the hen is molting, the feathers on different parts of the body are usually shed in the following order: head, neck, breast, body, wings, and tail.

In some individuals a few tail feathers may be shed before the wing feathers. Shortly after the old feathers are dropped, the new ones appear.

TABLE 20. DURATION OF ANNUAL REST (MOLTING) IN RELATION TO MONTH LAST EGG WAS LAID
(I. M. Lerner and L. W. Taylor, 1941)

Month last egg laid	Aug. and earlier	Sept.	Oct.	Nov.	Dec. and earlier
Average duration of rest, days	126	100	80	64	65

When the selection of layers is made in August or September, toward the close of the first laying year, the condition of the plumage is good evidence as to whether or not the birds are persistent producers. The

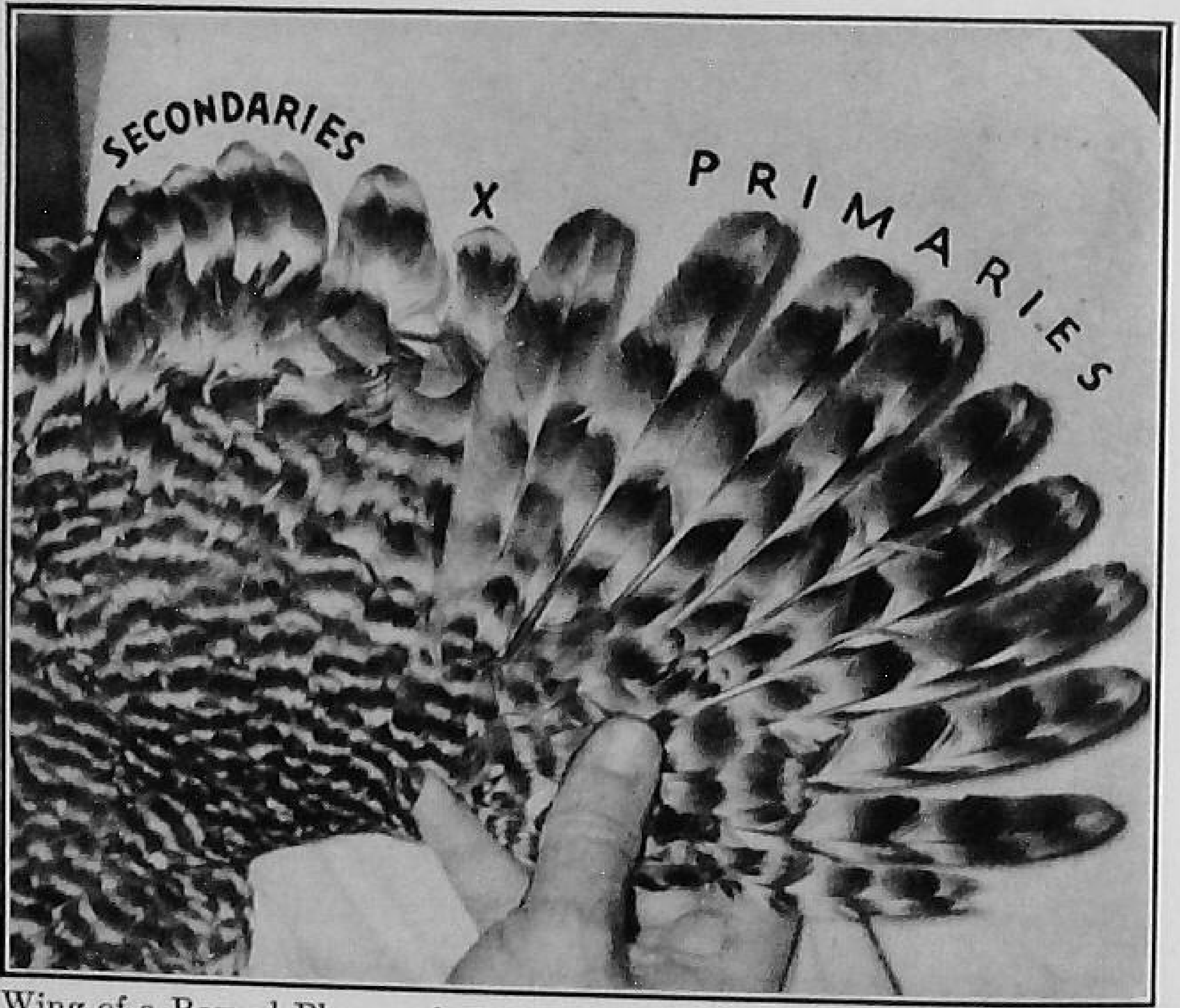


FIG. 66. Wing of a Barred Plymouth Rock showing 10 primary feathers, which are separated from the secondary feathers by the short axial feather, *X*. (*R. E. Phillips.*)

plumage of the continuous layers shows wear and tear from constant visits to the nest. The early-molting birds will have a growth of new feathers, the webs of which are glossy and bright in contrast to the dry, frayed webs of the old ones. The new quills are large, full, and soft, whereas the quills of the old feathers are small, hard, and almost transparent. A few pinfeathers in the neck may indicate a short molting period, but when shedding extends to the body and wings, the molt usually becomes a complete one. A bird usually stops laying when

molting the wing feathers, but may lay while molting in other parts of the body. If body weight is maintained, however, exceptionally high-producing hens may continue laying until the wing molt is well advanced.

Ordinarily, it is possible to estimate when the molt began by counting the primary feathers in the wing. The primary feathers are the stiff flight feathers seen on the outer part of the wing when it is spread out. The secondaries are also large and stiff, but they are found on the inner part of the wing close to the body. The primaries are separated from

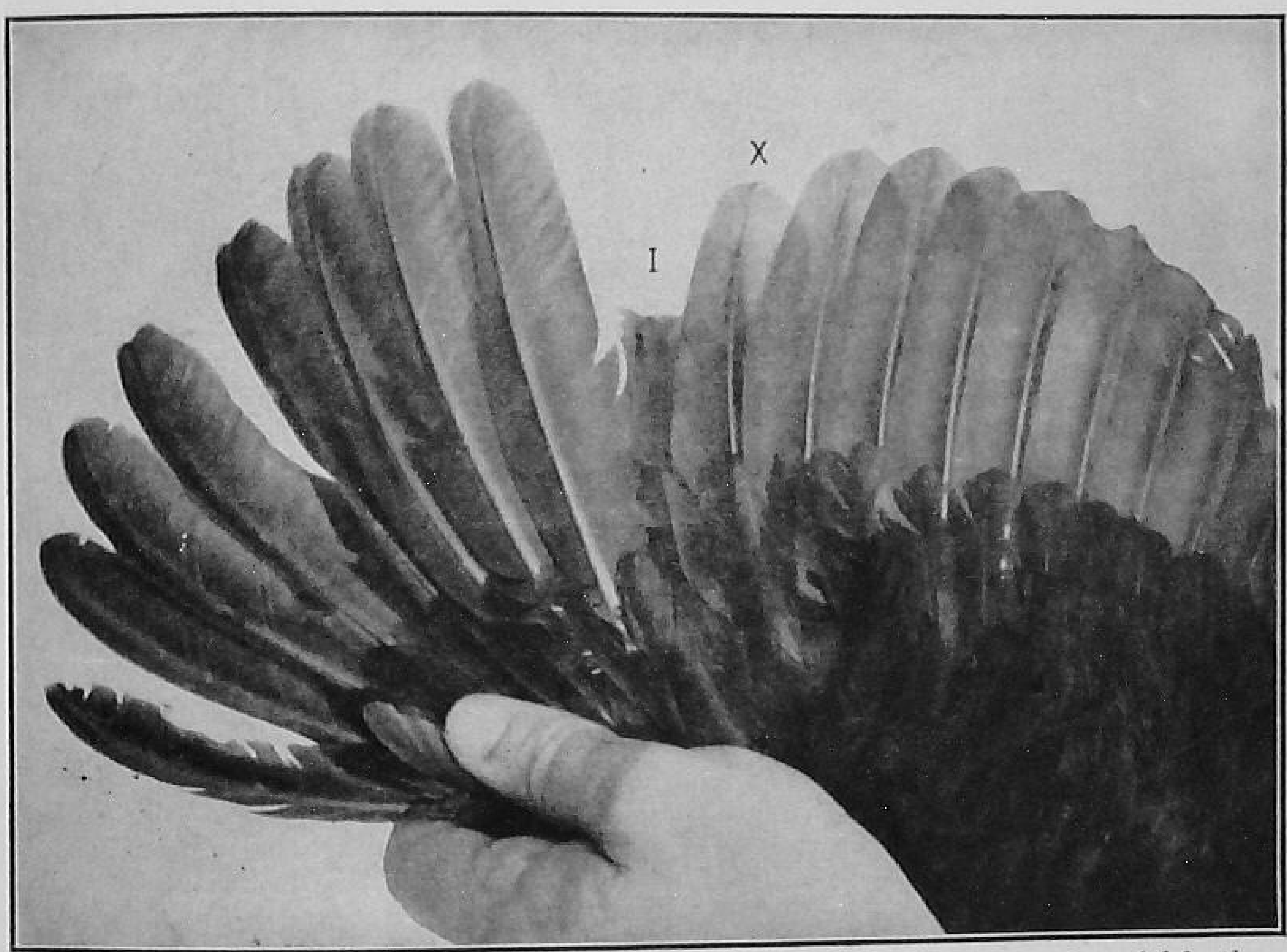


Fig. 67. Wing of a slow-molting bird. The first primary feather, next to the axial feather, *X*, is about one-half grown. The second primary is too small to be seen, and eight primaries remain to be shed. (*R. E. Phillips.*)

the secondaries by a much shorter feather, known as the "axial feather," which grows out at the wing joint. There are usually 10 primary feathers in each wing, and when the complete body molt begins, the first primary to be dropped is the inner one next to the axial feather.

In the case of the early molter, 2 weeks after the first primary is dropped the second one next to the axial feather is shed, and at 2-week intervals each subsequent primary is shed. In other words, when the new primary feather next to the axial feather is about one-third as long as one of the old primaries, the new primary is about 2 weeks old. In order to estimate the time elapsing since the molt began, 6 weeks should be allowed for the first mature new primary feather and 2 weeks for each

additional full-grown one. Thus, a wing having four new full-grown primaries shows that the bird has been molting 12 weeks. If the molt has just begun and none of the primaries is yet fully grown out, calculation must be made on their present growth. Approximately two-thirds of this growth is made during the first 3 weeks, and the other third during the last 3 weeks of growth. Approximately 24 weeks are required to complete the molt in most early molters.

FIG. 68. The wing of a fast-molting bird. Five primary feathers, shed at about the same time, are being replaced. (*R. E. Phillips.*)

While it is true that in early molters, for the most part, one primary feather is molted at a time, other birds molt two primaries at a time. In estimating the length of time that molting of primaries has been in progress, consideration must be given to double primary molting in late molters. A bird in which two primaries are molted at a time is usually a continuous producer and requires approximately 14 weeks to complete the molt.

The primaries of the continuous producer are molted rapidly, in a manner similar to that of the body plumage. Instead of being renewed one at a time, as in the early molter, a group of two or more primaries of the same length may grow simultaneously. When such a condition exists, all the new feathers of the same length are considered as one in calculating the length of time that has elapsed since molting began.

High-producing hens sometimes do not molt all of their primary feathers but continue to carry some of the old ones into the next year. By growing the primaries in groups of two or more, or carrying over the old primaries, many high producers materially shorten the time necessary to complete their wing molt. It is apparent, therefore, that the time and duration of the molt serves as a good criterion of continuous production.

Inheritance of Egg Production. The selection of birds based on the degree of depigmentation of the beak and shanks and on the time and duration of the annual molt is selection based on the appearance of birds. In order to make much progress in breeding for good egg production, birds for future breeding purposes must be selected on the basis of their genetic constitution.

There are five characters that largely determine the number of eggs produced during the first laying year. The selection of females for future breeding purposes on the basis of their performance with respect to each of these characters is an approach to the problem of selecting according to genotype. When selection is based on the average performance of full sisters (the female progeny of each dam) and of half sisters (the female progeny of each sire), the poultry breeder is more certain of the potential breeding worth of the birds chosen for breeding than when selection is on an individual-bird basis.

The following five characters largely determine the number of eggs produced during the first laying year: (1) age in days that laying commences, or sexual maturity; (2) intensity of production, or rate of laying; (3) the amount of broodiness; (4) pauses in laying; (5) persistency of production.

With respect to these five heritable characters, it is fairly simple for the pedigree-poultry breeder who trap-nests his birds to determine sexual maturity, approximate rate of laying, and persistency of production. This is fortunate because these three characters are more important than the other two. Selection for nonbroodiness and nonpauses is important, however, because otherwise egg production is lowered.

Sexual Maturity. By sexual maturity is meant the number of days between the date a pullet is hatched and the date she lays her first egg. Early sexual maturity is determined by at least two dominant genes, one autosomal and one sex-linked, although probably other genes are involved.

Among pullets hatched during the regular hatching season (February, March, and April) those hatched in the last part of this period show slightly retarded sexual maturity as compared with those hatched in the first part of this period. It has been suggested that this difference is associated with the relative length of daylight at date of first egg.

Since sex linkage is involved, only those males should be selected for

breeding purposes that are the progeny of early-maturing dams (especially if the dams' sisters were also early maturing), and further selection should be made on the basis of the earliness of sexual maturity of the cockerel's sisters. Females for breeding purposes should be selected on the basis of their earliness of sexual maturity and that of their dams and their sisters.

In order to produce a high first-year record, Leghorns should commence laying at about 150 to 160 days of age and general-purpose breeds at about 170 to 180 days of age.

Since the earlier in life that laying commences, usually the smaller the body size and the smaller the egg size at that time, it is important to maintain strains of Leghorns averaging about 3.5 lb. at sexual maturity

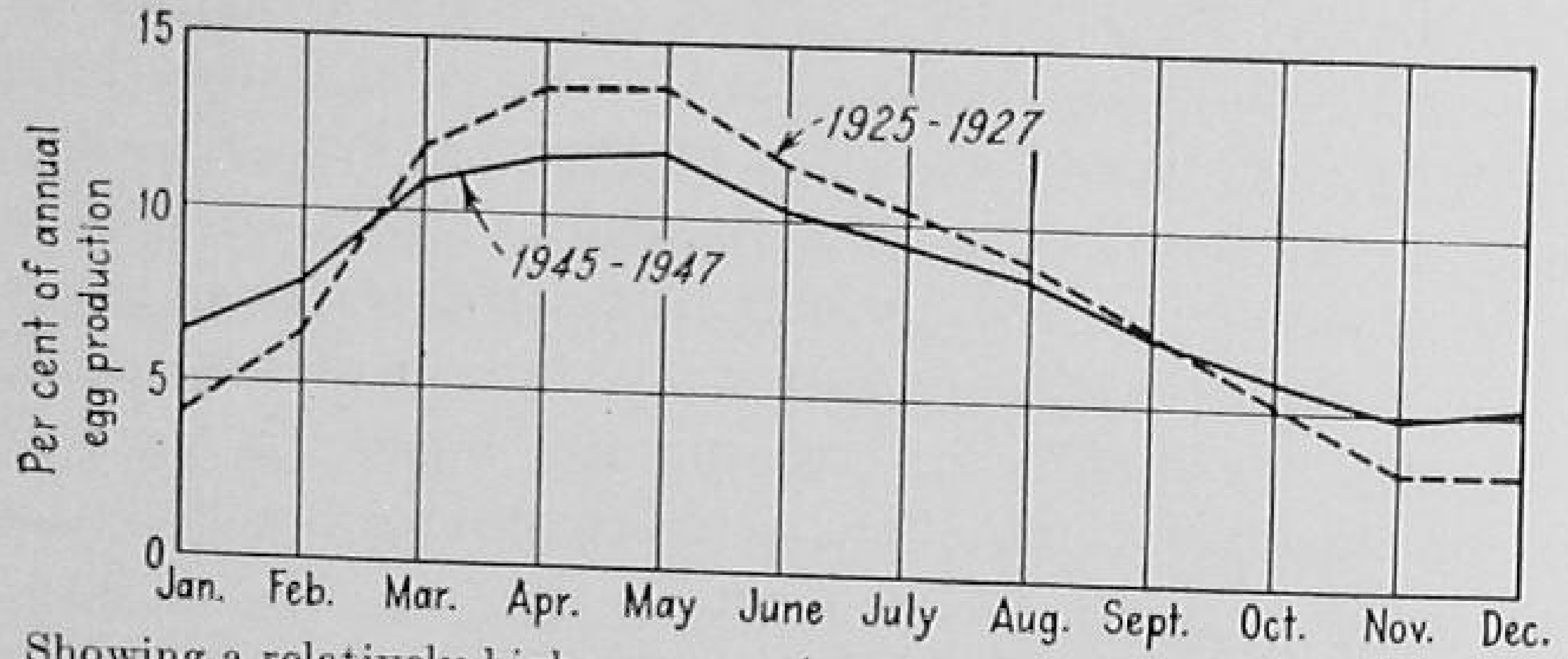


FIG. 69. Showing a relatively higher proportion of fall and winter egg production in 1945 to 1947 than in 1925 to 1927. This was due in part to earlier sexual maturity and a higher proportion of pullets in the laying flocks. On the basis of the number of birds housed at the beginning of each year, the average egg production per bird during 1925 to 1927 was 93 and during 1945 to 1947 it was 121. On a hen-day basis, the average egg production per bird during 1925 to 1927 was 117 and during 1945 to 1947 it was 155.

and strains of general-purpose breeds averaging about 5.0 or 5.5 lb. at sexual maturity.

Rate of Laying. The more eggs a bird lays in a given time, the higher the rate of laying. A bird that lays 5 eggs per clutch regularly naturally lays at a higher rate than a bird that lays 2 eggs per clutch regularly. At the same time, most pedigree breeders could hardly be expected to take the necessary time to determine rate in selecting breeders from among a large number of layers. The simplest way of determining rate for all practical purposes would be to divide the number of eggs laid during a relatively short period by the number of days involved. Another way would be to select on the basis of clutch size.

Broodiness. Two dominant complementary genes are apparently mainly responsible for broodiness, their complementary nature indicating that both genes must be present. In addition, sex linkage of broodiness has been demonstrated. Since broodiness reduces egg production, it is important to eliminate it from the strain in so far as possible. The most

effective way of reducing broodiness in a strain is to avoid using in matings any daughters of a dam that exhibited broodiness and any female and her sisters that exhibited broodiness, even though they are the progeny of a nonbroody dam, and especially to avoid using a male whose dam or sisters exhibited broodiness. The pedigree-poultry breeder can identify broody birds on his trap-nest record forms and thus select prospective breeders with a view toward reducing the amount of broodiness in his strain. The hatchery-flock owner can identify most of his broody birds by banding them when caught on the nest at night.

Winter Pause. Seven or more consecutive days, exclusive of broodiness, prior to Mar. 1 of the first laying year, during which no eggs are laid constitute a winter pause. Naturally, first-year production tends to be reduced. This character appears to be associated with net rate of laying.

Persistency. The longer that egg production is continued prior to the first annual molt, usually the greater the total first-year production. Persistency of production implies that a bird continues to lay well toward the close of her first laying year, cessation of production usually being followed by a complete molt, as pointed out previously. Age in days that the last egg was laid prior to the molt or the date of laying the last egg may be used to designate persistency. It should be noted, however, that occasionally a hen may continue laying throughout her molting period. Selection for persistency has been found to be effective.

Five Characters for High Records. Since each of the five characters discussed previously has been shown to be inherited, it is obvious that

TABLE 21. FIRST-YEAR EGG PRODUCTION IN PRODUCTION-BRED RHODE ISLAND REDS ACCORDING TO NUMBER OF DESIRABLE CHARACTERS
(F. A. Hays, 1944)

No. of desirable characters	No. of birds	Per cent of birds	Average egg production
1	10	0.82	125
2	69	5.66	157
3	393	32.21	188
4	439	35.98	224
5	309	25.33	252

birds possessing all five characters should lay better than birds possessing fewer characters. The data in Table 21 bear this out. No culling during the first laying year was practiced.

Knowledge gained concerning the influence of the five characters on first-year egg production has been of value to many poultry breeders in

selecting future breeding stock. The results secured from research on these five characters have led to the adoption of improved breeding programs to increase egg production. Some of these programs are discussed later.

Part-time Trap-nesting. Trap-nesting a flock of birds every day in the year in order to determine the total number of eggs laid by each bird during her first laying year involves considerable labor and is, therefore, quite expensive. However, since the exact number of eggs laid by a bird is not of very great importance, it is possible for pedigree-poultry breeders to save considerable time in trap-nesting the flock and still secure a reliable index of the approximate number of eggs laid by each bird.

Trapping birds 3 days a week provides a reliable basis for estimating first-year egg production. A bird laying 99 eggs on a 3-days-a-week basis would be estimated to have laid $99 \div 3 = 33 \times 7 = 231$ eggs during the year.

This system of short-time trap-nesting is particularly justifiable when the average egg production of each family of full sisters is taken into consideration in selecting future breeding stock. Trapping 3 days a week would enable a poultry breeder to trap-nest twice as many birds as compared with trapping 6 or 7 days a week. There would thus be a chance of progeny-testing twice as many sires and dams.

Yearly Decline in Egg Production. It is well known that birds usually do not lay so well in their second laying year and in later years as in their

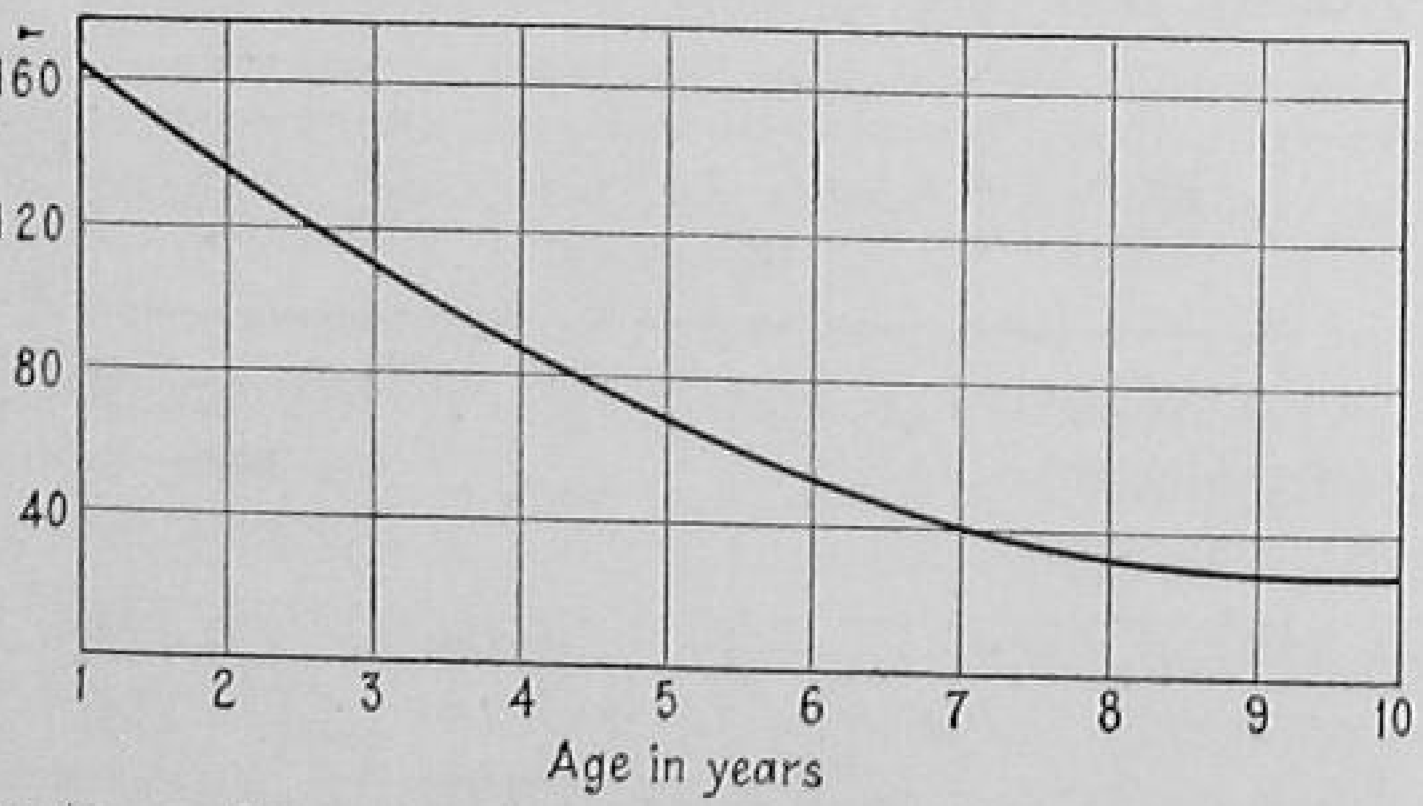


FIG. 70. Decline in yearly egg production in White Leghorns in relation to age. The second-year production was 19 per cent below the first-year production. (*T. B. Clark.*)

first laying year. A decline of as much as 15 per cent or more is considered normal, the decline being relatively greater each succeeding year in the case of general-purpose breeds than in the case of Leghorns. It is for this reason that many commercial-egg producers maintain flocks of pullets exclusively. The problem of using pullets as compared with yearling and older hens for breeding purposes is discussed later.

Effects of Inbreeding. Inbreeding is practiced by some poultry breeders with a view toward developing strains possessing many of the genes that determine high egg production.

It is highly probable that most pedigree-poultry breeders practice some mild inbreeding, such as mating cousins. This would be more apt to be true in the case of poultry breeders with few breeding pens than in the case of poultry breeders with many breeding pens, although many of the latter deliberately mate related birds in order to test the merits of such matings. Quite a few breeders occasionally mate full brothers and sisters and more frequently half brothers and sisters. This is close inbreeding, and if the progeny of each of these closely inbred matings is again full-brother-and-sister or half-brother-and-sister mated for a few years in succession, this intensive inbreeding leads to the development of inbred lines.

The progeny of inbred lines may be used in different ways. Males of one inbred line may be mated with noninbred females of the same breed or variety, such a practice being called top-crossing. Males of an inbred line mated with noninbred females of another breed or variety is a form of crossbreeding. Males of one inbred line mated with females of another inbred line of the same breed or variety is another use to which inbred lines can be put.

The results secured from inbreeding to increase egg production depend to a considerable extent on the breeding quality of the parental strains used. The data given in Table 22 pertain to egg-production records for 3 or more years secured from the progeny of matings of outbred White Leghorns and outbred Rhode Island Reds, respectively, and from matings of inbred Rhode Island Red males to each of four kinds of females, (1) outbred Rhode Island Red females, (2) unrelated inbred Rhode Island Red females, (3) related inbred Rhode Island Red females, and (4) inbred White Leghorn females.

TABLE 22. FIRST-YEAR EGG PRODUCTION OF PROGENY IN RELATION TO DIFFERENT KINDS OF MATINGS
(C. W. Knox, 1946)

Kind of Mating	Average 1st-year Egg Production of Progeny
Outbred W. Leghorn males and females	195
Outbred R. I. Red males and females	189
Inbred R. I. Red males × outbred R. I. Red females	191
Inbred R. I. Red males × unrelated inbred R. I. Red females	198
Inbred R. I. Red males × related inbred R. I. Red females	182
Inbred R. I. Red males × inbred White Leghorn females	224

The egg-production records given in Table 22 are quite similar except in the case of the last two matings, 182 and 224 eggs. This is a difference of 42 eggs in favor of the progeny of inbred White Leghorn females over the progeny of inbred Rhode Island Red females that were unrelated to the inbred Rhode Island Red males to which both groups of females were mated. It should be kept in mind, of course, that with other strains of White Leghorns and Rhode Island Reds different results might have been secured.

It has been pointed out previously that the results secured from inbred matings depend a great deal upon the quality of the parental strains used in the original matings. As a matter of fact, the results secured from close or intensive inbreeding often bring to light certain inherent weaknesses in the parental strains. Also, when intensive inbreeding is practiced, rigid selection of the breeding stock must be made each year on the progeny-test basis to maintain a satisfactory level of hatchability. Without adequate selection on the basis of hatchability, intensive inbreeding is liable to result in the loss of entire families. Rigid selection of the breeding must also be practiced for other characters, or they are apt to deteriorate. In the hands of a skillful pedigree breeder, intensive inbreeding is a very useful procedure in developing strains possessing many genes that determine high egg production.

Many hatchery-flock owners and farm poultrymen are concerned about the danger of inbreeding within their own flocks if some outbreeding is not practiced occasionally. The progeny of mass matings involving approximately 300 or more females is not liable to suffer from excessive inbreeding for several years.

It has been shown that inbred sires from outstanding high-producing strains mated to females of the same variety in hatchery flocks sometimes produce progeny that lay much better than the original flocks.

Effects of Crossbreeding. Very little experimental work has been carried on to determine the effects of crossbreeding on egg production. Poultrymen who cater to a white-egg market should avoid the crossbred progeny secured from crossing White Leghorns and any of the general-purpose breeds or varieties because the crossbred progeny lay tinted eggs. On the other hand, throughout the northeastern section of the United States many commercial laying flocks consist entirely of black pullets secured from crossing Rhode Island Red males and Barred Plymouth Rock females, these males and females being from high-producing strains. One noticeable effect that usually results from crossbreeding is increased broodiness in the crossbred progeny. An illustration of results with respect to egg production secured from crossbreeding is given in Table 23.

The data in Table 23 show that the egg production of the crossbred

TABLE 23. FIRST-YEAR EGG PRODUCTION OF PROGENY IN RELATION TO KIND OF MATINGS
(C. W. Knox, J. P. Quinn, and A. B. Godfrey, 1943)

Kind of Mating	Average 1st-year Egg Production of Progeny
Rhode Island Red males × Rhode Island Red females	192
Light Sussex males × Light Sussex females	140
White Wyandotte males × White Wyandotte females	154
Rhode Island Red males × Light Sussex females	172
Rhode Island Red males × Wyandotte females	163

progeny was about midway between the egg production of the purebred progenies of the parental breeds. In other words, in this case, the inferior laying ability of the strain of Light Sussex and of White Wyandottes resulted in decreased egg production of the crossbred progenies as compared with the egg production of the purebred Rhode Island Reds.

BREEDING FOR IMPROVED EGG QUALITY

In addition to breeding for high egg production, there is much need for improving the inherent quality of market eggs produced by most flocks of the country. The following five egg characters are of considerable economic importance: (1) good size, (2) proper shape, (3) strong shells, (4) uniform shell color, (5) good interior quality. Since these are five hereditary characters, it should be possible for pedigree-poultry breeders to render a valuable service to the poultry industry by developing breeding stock for hatchery flocks which serve as a source of hatching eggs from which are secured most of the chickens that are raised every year. An improvement in egg-quality characters would benefit market-egg producers and would give increased satisfaction to consumers.

Good Egg Size. Egg size and egg weight are synonymous in so far as new-laid eggs are concerned; the larger the size the heavier the egg. On the other hand, eggs held for some time in a dry and warm room lose weight without shrinking in size. This matter is mentioned here only because it should be understood that when the terms "egg size" and "egg weight" are used interchangeably in the literature, they deal with new-laid eggs.

With respect to market eggs, a 2-oz. egg is considered to be standard market size. A 2-oz. egg weighs 56.7 g. One dozen such eggs weigh 24 oz. (1.5 lb.) or 680.4 g. This item is mentioned here because much of the literature on the inheritance of egg size or egg weight deals in terms of grams.

When pullets commence laying, they are still in a growing state.

Maximum body weight during the first laying year is usually attained by about February or March. Maximum egg weight is usually attained by February, or by March in the case of some general-purpose strains. After maximum body and egg weight are attained, there is usually a decline in both to about July or August and then a slight increase to the end of the first laying year. Body-weight and egg-weight trends are shown in Fig. 71, body and egg weights having been determined on a monthly basis.

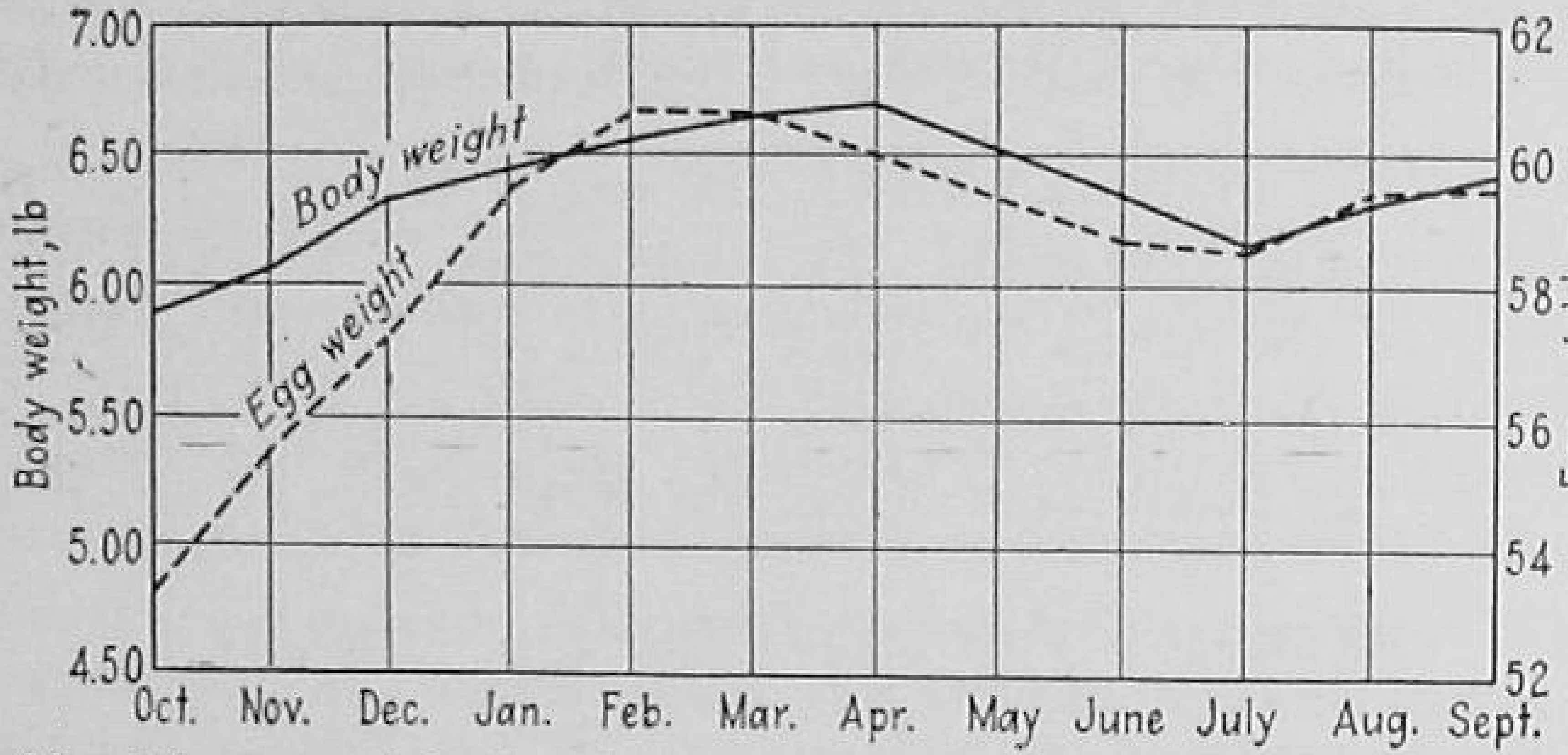


FIG. 71. Monthly egg weight in relation to monthly body weight during the first laying year in Rhode Island Reds. (*F. A. Hays.*)

The earlier in life that laying commences, usually the smaller the size of the first eggs laid and the longer the time required to attain maximum monthly egg size.

It is possible, however, to develop strains of pullets that will lay eggs of maximum monthly weight as early as December, as shown in Table 24. The results, in this case, were secured by selecting breeding stock each year on the progeny-test basis. The average annual egg weight is also given.

TABLE 24. FIRST MONTH STANDARD OR MAXIMUM EGG WEIGHT WAS ATTAINED AND AVERAGE ANNUAL WEIGHT OF EGGS, WHITE LEGHORNS
(M. W. Olsen and C. W. Knox, 1940)

Year	First month standard or maximum egg weight was attained			Average annual egg weight	
	Month	Grams per egg	Ounces per dozen	Grams per egg	Ounces per dozen
1935 to 1936	March	56.7	24.0	55.7	23.6
1936 to 1937	Feb.	56.7	24.0	56.8	24.0
1937 to 1938	Jan.	57.4	24.3	58.5	24.9
1938 to 1939	Dec.	56.8	24.0	59.7	25.3

The data in Table 24 not only show that the month of attaining standard or maximum monthly egg weight was advanced each year, but that the average annual egg weight increased. The breeding stock was selected on a progeny-test basis by paying particular attention to the average weight of eggs laid by full-sister families.

Effect of Date of Hatch. The preceding discussion on changes in egg weight that take place during the first laying year apply to pullets hatched during the regular hatching season. Pullets hatched in November and December tend to lay a relatively large number of small- and medium-sized eggs. Pullets hatched in June and September tend to lay a relatively large number of medium-sized eggs.

Effect of Hot Weather. In southern sections of the country, egg size tends to decrease with the approach of hot weather, and under certain circumstances a slight allowance might be made for this fact. Whether the effect is due directly to hot weather or to decreased feed consumption and decreased body weight resulting from hot weather has not been determined.

Determining Average Annual Egg Size. Since egg and body size are inherited characters, a breeding program designed to develop a strain of pullets that lays eggs of good size should be based on the average weight of a minimum number of eggs at certain times during the first laying year. It is not necessary to weigh all the eggs laid during the year. Any one of the following methods may be used to determine the average first-year egg weight, which should be a minimum of 24 oz. per doz.: (1) Weigh eggs on a given day each week throughout the year; (2) weigh eggs on 4 consecutive days of each month throughout the year; (3) weigh eggs on the same day each week for any 4 consecutive months between Jan. 1 and July 1; (4) weigh eggs on 3 consecutive days of each month from February through May; (5) weigh the first 10 eggs laid by each bird during her fifth month of laying; (6) weigh the first 10 eggs laid by each bird during March.

Methods 2 and 3 are used by many pedigree-poultry breeders. Methods 5 and 6 are probably the simplest ones to use, although in each case the 10 eggs should average at least 25 oz. per doz. to ensure an average first-year weight of 24 oz. per doz.

Second- and Third-year Egg Weight. The mean weight of eggs laid during the second and third laying years is usually higher than the mean weight of eggs laid during the first laying year, the third-year mean weight being slightly lower than the second-year mean weight (see Table 25).

The data in Table 25 pertain to a selected group of birds whose first-year egg weight was somewhat higher than would be the case with all

the pullets in the average flock. As compared with birds in their second and later laying years, pullets in their first-laying year are handicapped in the matter of annual egg weight by the number of relatively small eggs they lay the first 2 or 3 months.

TABLE 25. EFFECT OF AGE OF LAYERS ON MEAN ANNUAL EGG WEIGHT
(F. A. Hays, 1944)

No. of birds	First laying year		Second laying year		Third laying year	
	Grams per egg	Ounces per dozen	Grams per egg	Ounces per dozen	Grams per egg	Ounces per dozen
24	61.2	25.9	64.5	27.3	63.8	27.0

Egg Size Inherited. From all available evidence it is apparent that egg size is determined by several genes. Sires and dams transmit egg size equally. Also, there is a significant interaction between genetic contributions of sire and dam.

Breeding stock should be selected from among the progeny of dams that laid eggs having a mean annual egg weight of not less than 24 oz. per doz. Further selection should be made on the basis of each pullet's egg weight.

Good Egg Shape. The production of eggs of proper shape is important from the marketing standpoint. Standard egg cases, flats, and fillers accommodate eggs not over $2\frac{13}{32}$ in. long and $1\frac{25}{32}$ in. wide. Excessively long eggs are liable to be crushed and excessively wide eggs are difficult to fit into the fillers properly. For the most part, all eggs laid by each bird are of a characteristic shape. In other words, egg shape is a hereditary character.

Egg shape is measured by determining shape index, the greatest width being divided by the greatest length and the product multiplied by 100. In one experiment two lines differing in shape index were developed from an original flock whose eggs had an average shape index of 72.00. The fifth year of selection in developing a relatively roundish-egg line and a relatively long-egg line yielded the results given in Table 26. The male and female breeders used in this experiment were selected on the basis of shape index of their dams and their full sisters.

The data given in Table 26 indicate that egg shape is a hereditary character and that in flocks where improvement in egg shape is desirable, a sound breeding program would be worth while.

Strong Shells. Many thousands of dollars are lost every year due to egg breakage on the farm and in marketing channels. Thin-shelled eggs

are sometimes due to deficiencies of certain nutrients in the diet. High temperatures during the laying season reduce eggshell thickness. At the same time, eggshell thickness is an inherited character. The thicker the shell, the more resistant it is to breakage when eggs are subjected to rough handling.

TABLE 26. EGG-SHAPE INDEX OF DAUGHTERS OF MATINGS WITHIN A "ROUND-EGG LINE" AND A "LONG-EGG LINE," RESPECTIVELY
(D. R. Marble, 1943)

Line	Mean egg-shape index of			Per cent of daughters laying	
	Sire's dam and sisters	Dams' dams and sisters	Daughters	"Round"	"Long"
"Round"	77.31	79.30	76.89	97.3	2.7
"Long"	62.23	66.41	69.29	11.8	88.2

Shell thickness and strength are related to the porous nature of the shells. One method used in measuring shell quality has been to determine the relative loss in weight of eggs when incubated for 14 days in a forced-draft incubator at 99.5°F. and 60 per cent relative humidity.

From an original flock of White Leghorns, two lines were developed differing in egg-weight loss. Cockerels for breeding purposes were selected from families of full sisters whose eggs showed the least and the greatest loss in weight, respectively. The females used for breeding purposes consisted of progeny-tested dams and pullets from families of full sisters whose eggs showed the least and the greatest loss in weight, respectively. The eggs of all the progeny of each line were tested for loss in weight. The line showing the least loss in egg weight naturally laid eggs with good shells, and the line showing the greatest loss in egg weight laid eggs with poor shells. The extent to which the lines differed during 7 years of selection and breeding is shown in Fig. 72.

It is clearly apparent from Fig. 72 that shell quality is inherited and can be improved by progeny-testing dams and by selecting cockerels and pullets for breeding purposes from families in which the full sisters' egg-weight loss was the least. In eggs having good shell quality, the thick white does not break down so readily in warm weather as in eggs having poor shell quality.

Determining the specific gravity of eggs is a reliable method of measuring differences in shell thickness among eggs. Variations in the specific gravity of eggs are due largely to variations in shell thickness.

Uniform Shell Color. Breeding for uniform shell color is of importance in breeds laying white-shelled eggs and in breeds laying brown-shelled eggs. In some flocks of White Leghorns some of the birds lay tinted eggs. From the market standpoint, these tinted eggs are objectionable because consumers who regularly buy white-shelled eggs prefer to have them uniform in color. In many White Leghorn flocks, the first few eggs laid by pullets may show a slight tint. This should cause no particular concern. However, White Leghorns that lay tinted eggs after having been in production for some time should be eliminated from the flock, and none of their progeny should be used as breeders.

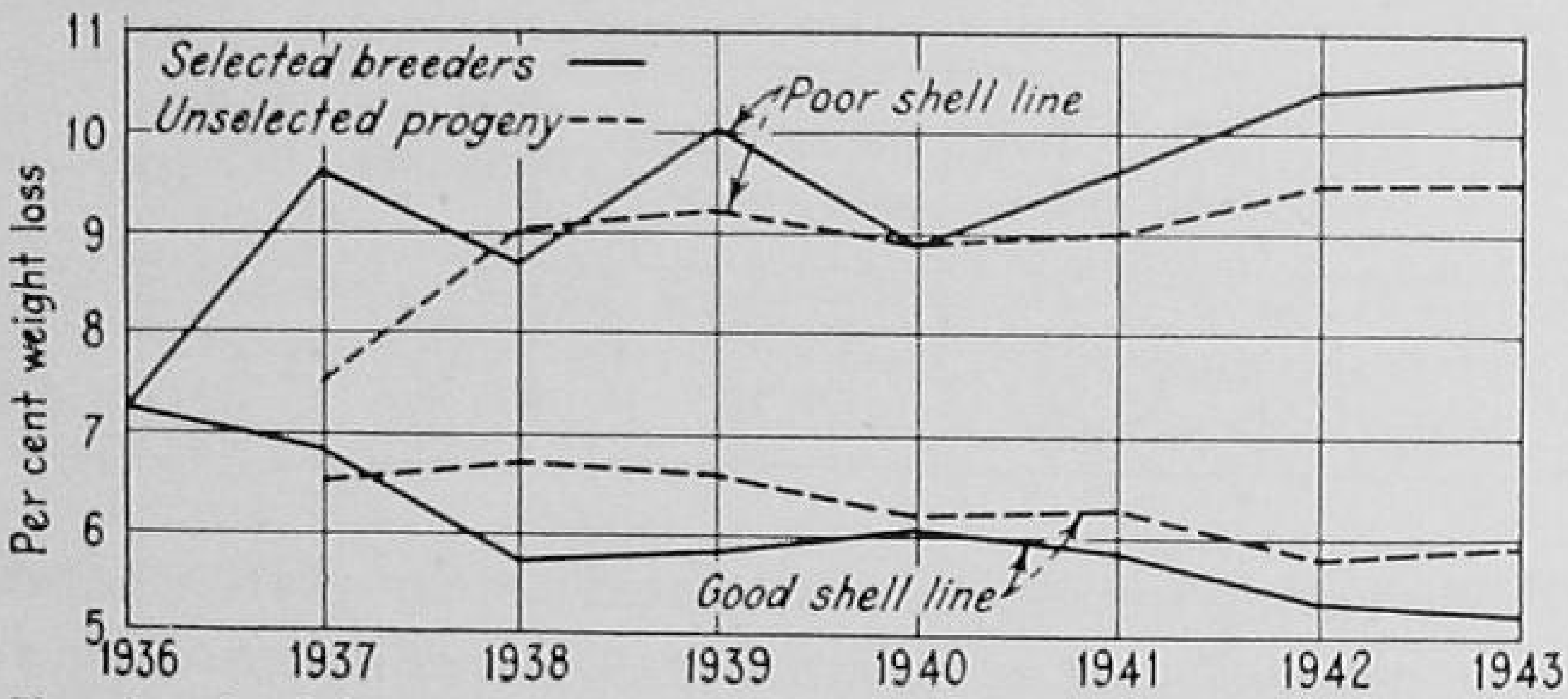


FIG. 72. Showing the difference in per cent loss in egg weight during 14 days of incubation at 99.5°F. between two strains of White Leghorns developed by selection and breeding from the same original flock. After 7 years the difference in weight loss between the two strains of breeders was 5.3 per cent and between the two strains of progenies was 3.6 per cent. (*J. P. Quinn, C. D. Gordon, and A. B. Godfrey*, 1945.)

Eggs laid by the general-purpose breeds usually vary considerably in color. From the consumers' standpoint this apparently is relatively unimportant, although a uniform color is desirable.

Good Interior Quality. Since consumers normally prefer eggs with a high per cent thick white of total white, it is interesting to note that this character is inherited. Carrying on a sound breeding program should improve the character, as shown in Fig. 73.

Another hereditary character of considerable importance with respect to market eggs is the presence of blood clots and blood spots. Other factors, such as diet, probably play a part. From various published reports it appears that general-purpose breeds tend to lay eggs containing relatively more blood clots and blood spots than White Leghorns.

Probably most of the blood clots and blood spots originate as hemorrhages between the vitelline membrane of the yolk and the inner surface of the follicle prior to ovulation. Blood clots and blood spots may also result from slight hemorrhages of the blood vessels of the oviduct. So-called "meat spots" that have been reported as being present in eggs are, for the most part, degenerated blood clots resulting from changes

that take place while the clot is surrounded by egg white, these changes being hastened by relatively high temperatures. Some of the "meat spots" apparently may be pieces of follicular tissue grasped by the mouth of the oviduct at the time of ovulation. The incidence of blood clots and

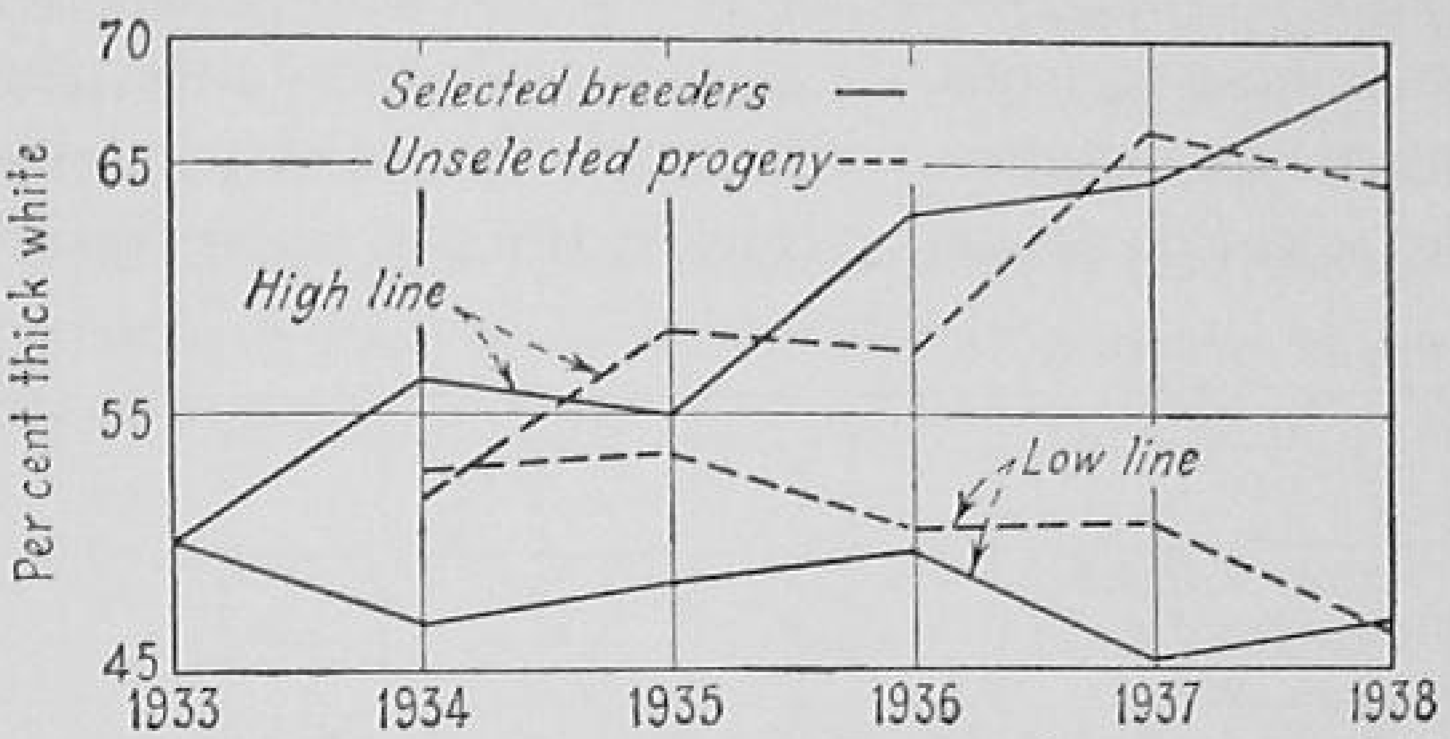


FIG. 73. Showing the difference in per cent thick white between eggs laid by two strains developed from the same original flock by selection and breeding. After 5 years, the eggs of the selected breeders showed a 21.9 per cent difference in per cent thick white, and the eggs of their progenies showed a difference of 17.5 per cent. (*C. W. Knox and A. B. Godfrey*, 1940.)

blood spots can be reduced by the adoption of a progeny-test breeding program.

METHODS OF SELECTING BREEDING STOCK

The ability to select males and females of superior breeding worth is the first requisite of a successful breeding program. In selecting males and females for future breeding purposes, proper value should be given to each character based on its relative economic importance. Since most poultry breeders are interested in so many characters, however, it is often difficult to determine the relative value of each of the various characters in selecting future breeders. The following list of desirable characters are those which most pedigree-poultry breeders take into consideration in their breeding program:

1. *Physical characters.* Good breed type, reasonably good plumage color, freedom from defects, and freedom from disqualifications.
2. *Egg-production characters.* Early sexual maturity, high rate of laying, nonbroodiness, nonpauses, and persistence of production.
3. *Egg-quality characters.* Standard egg size, good egg shape and color, uniform shell texture, high per cent thick albumen, and freedom from blood clots and spots.
4. *High hatchability.*
5. *High viability of growing stock and layers.*
6. *Meat-production characters.* Rapid growth, early feathering, superior breast fleshing, and good body size.

From an economic standpoint, the most important characters include egg production, egg size, interior egg quality, hatchability, viability, rate of growth, and breast fleshing.

Selection on the Basis of Total Score. The list of desirable characters given above indicates that the poultry breeder must consider many different characters in his selections, giving relatively more attention to those of greatest economic importance. The larger the number of characters considered in the selection program, the less the attention likely to be given

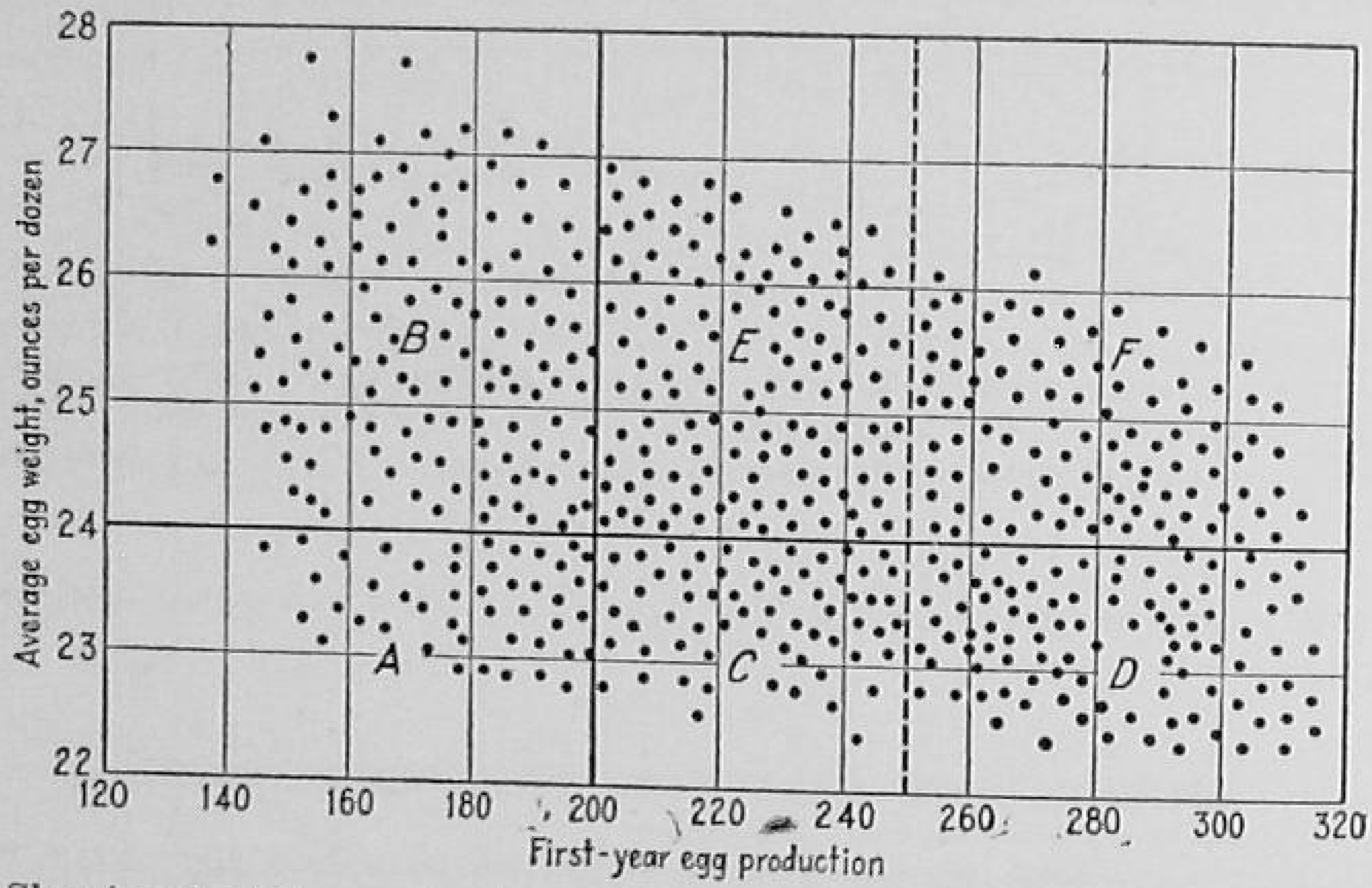


FIG. 74. Showing the difference in the proportion of birds saved for breeding purposes when the basis of selection is: (1) a minimum of 200 eggs per bird averaging 24 oz. per doz., vertical and horizontal solid lines; (2) a minimum of 250 eggs per bird averaging 24 oz. per doz., vertical dash line and horizontal solid line. Each dot represents a bird's first-year egg production and the average weight of her eggs. Under (1), all birds in sections *A*, *B*, *C*, and *D* are discarded. The birds in sections *E* and *F* are saved for breeding purposes; they constitute about 40 per cent of all the birds. This is not intense selection. Under (2), all the birds except those in section *F* are discarded; the section *F* birds constitute about 10 per cent of all the birds.

to any one character. Some characters, such as plumage color and various defects, are not related to egg production, hatchability, rate of growth, and other strictly economic characters. The more attention paid to characters of lesser importance from the economic standpoint, the slower the progress in improving the economic characters. On the other hand, the poultry breeder must keep in mind all characters that affect the average merit of the strain.

The poultry breeder, therefore, must use a method of selecting males and females for future breeding purposes on the basis of the relative importance of the various characters listed previously. He may use one of three methods of selection and breeding: (1) selecting and breeding for one character at a time; (2) selecting and breeding simultaneously but

independently for each of the characters; (3) selecting on the basis of total score, which serves as a measure of net merit.

The first method consists of selecting and breeding for one character at a time and, after that character has been improved to the desired standard, selecting and breeding for another character, and so on. This is the least effective method of the three and requires too long to make over-all improvement.

The second method, selecting and breeding simultaneously but independently for each character, is not so effective as the third method but

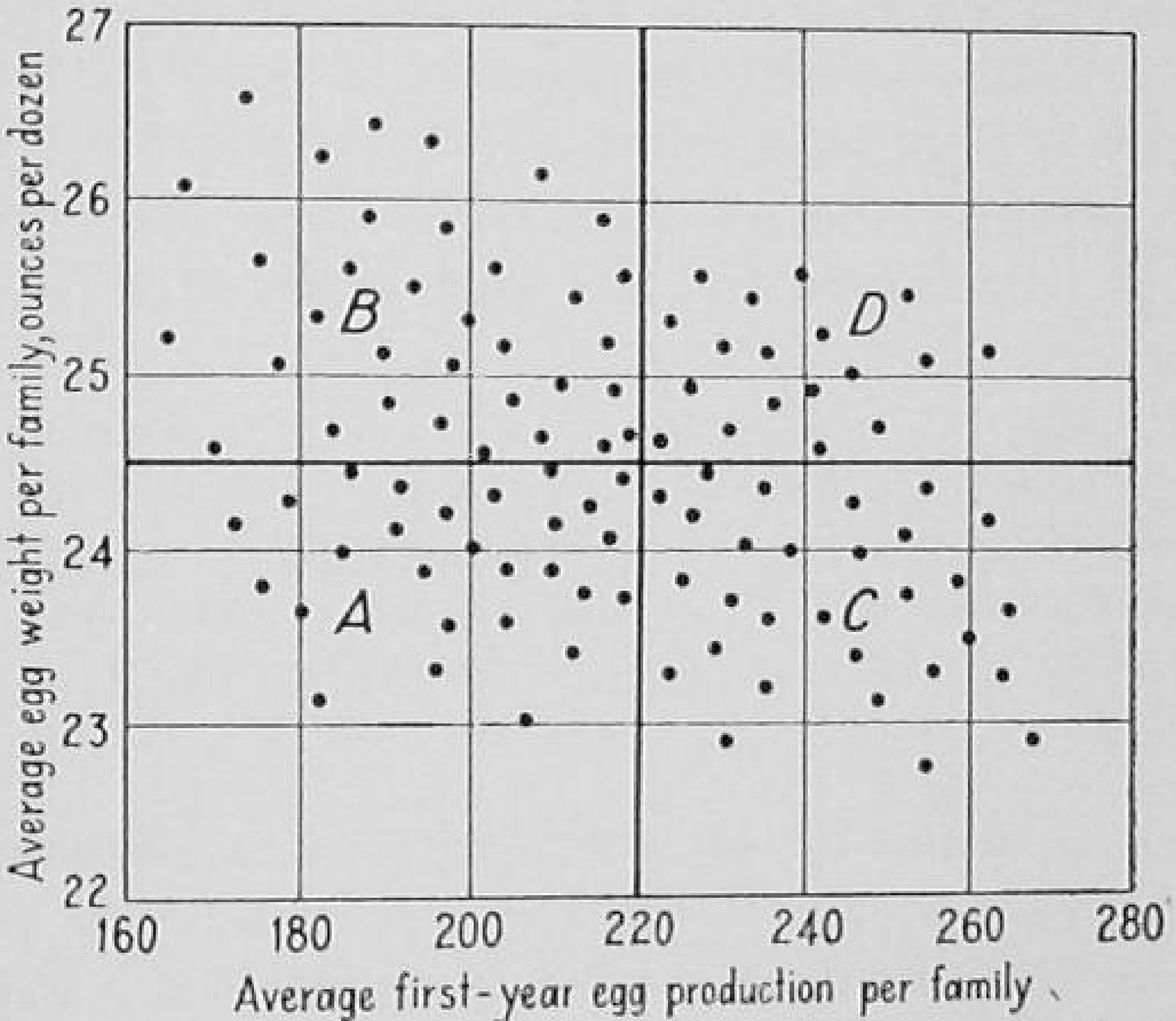


FIG. 75. The selection of breeding stock should be made on a family basis. Each dot represents the average first-year egg production and average egg weight for a family of at least six full sisters. The basis on which families are selected for future breeding purposes is a family average of at least 220 eggs weighing at least 24.5 oz. per doz. at time of laying maximum-sized eggs. The families in sections *A*, *B*, and *C* are discarded regardless of the first-year egg production and average egg weight of any individuals belonging to these families. Section *D* families constitute about 16 per cent of all the families, and the birds belonging to these families should make superior breeders.

has the advantage of making possible the culling of birds as soon as any undesirable character becomes evident.

The third or total-score method consists of selecting and breeding for all desirable characters simultaneously by using a score of net merit. This is done by adding a bird's scores for its net merit in each of the various characters, those with the highest total score being saved for future breeding purposes and those with the lowest scores being culled. The score of net merit is based on the degree to which the individual is superior or inferior in each desirable character.

It is obvious, of course, that the development of a total-score method of selection involving all the characters listed previously would be quite complicated. The procedure could be simplified considerably by con-

sidering egg production, egg size, and two or three other characters having the greatest economic importance. Moreover, a total-score method of selection based on family averages would be superior to one based on individual performance.

Selection on the Basis of Progeny Test. The discussion in the preceding pages of this chapter indicates that relatively little is known concerning the mode of inheritance of most of the characters of economic importance. The five characters that determine the total number of eggs laid during the first laying year and such characters as rate of growth and breast fleshing are so greatly affected by environmental conditions that selection of future breeding stock must be based on family averages if much progress is to be achieved in improving a strain.

In order to make up the best kind of matings, prospective sires and dams should be selected on the following basis, prior to the hatching season:

	Sire	Dam
1.	Family size (at least 6 full sisters)	Family size (at least 5 full sisters)
2.	Family physical characters	Family physical characters
3.	Family egg production	Family egg production
4.	Family egg quality	Family egg quality
5.	Family viability	Family viability

The selection of males for breeding purposes is extremely important for the simple reason that each sire has several times as many progeny as each dam to which he is mated. The selection of a superior male is more likely to be made if the egg production and egg-weight records of his half sisters as well as his full sisters are taken into consideration at the time of making the selection.

Based on the results secured during the hatching season and for the period from hatching time to the time the pullets are to be housed, further selection should be made on the following basis:

	Sire	Dam
1.	Fertility of mates (8 or more)	Fertility
2.	Hatchability of mates	Hatchability
3.	Viability of progeny	Viability of progeny
4.	Rate of growth of progeny	Rate of growth of progeny
5.	Rate of feathering of progeny	Rate of feathering of progeny
6.	Breast fleshing of progeny	Breast fleshing of progeny
7.	Physical characters of progeny	Physical characters of progeny
8.	Number of daughters (50 or more)	Number of daughters (8 or more)

The daughters trap-nested should be representative of all those secured from each sire and each dam for the progeny test to be a reliable measure to use in selecting cockerels and pullets for future breeding

purposes. Excessive culling tends to give a distorted picture of the breeding worth of sires and dams. From the practical standpoint, however, some culling is necessary in order to save feed on inferior layers and to salvage the meat value of these birds. Accurate records should be kept on a family basis.

The superior value of the progeny of progeny-tested breeding stock over the progeny of non-progeny-tested breeding stock is shown in Table 27.

TABLE 27. AVERAGE INCOME PER BIRD FOR PULLETS FROM PROGENY-TESTED VERSUS PULLETS FROM NON-PROGENY-TESTED STOCK, CALIFORNIA, 1937 TO 1948
(L. D. Sanborn and A. D. Reed, 1949)

Item	Pullets from progeny-tested breeding stock	Pullets from non-progeny-tested breeding stock
No. of farms	116	173
Average egg production per bird	182.0	164.9
Average egg production per bird in fall	53.1	44.4
Per cent mortality	20.4	21.1
Per cent culled	69.0	68.9
Average income per bird, dollars	2.14	1.78

Shortening the Trap-nest Period. When birds are trap-nested for 365 days after commencement of laying, many birds do not complete their first year of laying until late in the fall. In many cases the poultry breeder is not able to determine the average first-year egg production until late November or sometime in December. This often makes it difficult to get the laying house properly prepared in time for the new crop of pullets.

This difficulty could be overcome to a large extent by shortening the trap-nesting period to 300 days. Not only would much labor be saved in trap-nesting but, from the standpoint of carrying on a sound breeding program, family records computed on a 300-day basis should be just as valid in determining the relative breeding worth of the sires and dams of those families as family records computed on a 365-day basis.

Another advantage of a 300-day or some similar period for terminating the trap-nesting of pullets would be that all inferior families could be transferred to range shelters and given artificial lighting, if possible, in order to secure as many eggs as possible before the first annual molt.

If the proper kind of a progeny-testing program is carried on, a goodly proportion of the cockerels and pullets secured each year should be

superior to their parents in breeding worth. This being the case, progress in improving a strain would be hastened if several matings of carefully selected cockerels and pullets were maintained each year in addition to matings of progeny-tested hens. Breeding from pullets not only reduces the interval between generations but enhances the chances of selecting and mating potentially superior breeders. If the poultry breeder is carrying on a sound selection and breeding program, each succeeding generation should be better than the preceding generation, although probably not so good as the selected parents from which it originated. However, when pullets are used for breeding purposes, they should be carefully selected on a family basis.

Breeding from Pullets. It has been demonstrated by geneticists at the University of California that the heritability of egg production is reasonably uniform throughout the first laying year. With respect to the selection of birds as potential breeders, it has been established that the rate of progress expected in breeding for increased egg production "is equal to the intensity of selection multiplied by the interval between generations." It was found that about 50 per cent of the genetic variance in first-year egg production was accounted for by the record of egg production to the end of December of the year in which the birds were hatched.

Since it was determined that the "genetic gain per generation when selection is practiced on the basis of part records to the end of December is about two-thirds of that expected if selection were based on the full annual record," it is obvious that the poultry breeder would make greater progress in developing high-laying strains by using pullets selected on the basis of their laying performance to Dec. 1 or Jan. 1 of their first laying year. The selection of the pullets should be made on the basis of the average egg production per family.

In selecting pullets for breeding purposes, egg size should also be taken into consideration. Pullets whose last 10 eggs laid in November weighed an average of 22.5 oz. per doz. should attain an average of about 24 oz. per doz. for the first laying year.

Mortality on a family basis from hatching time to selection time should be considered before the final selection of breeders is made.

Improving Hatchery Flocks. Since approximately 90 per cent of the chickens raised in the United States every year are secured as chicks from hatcheries, it is obvious that there is great need of improvement in the breeding quality of many thousands of hatchery flocks.

Hatchery operators should secure hatching eggs or chicks each year from pedigree-poultry breeders who carry on a progeny-testing program. Using well-bred males in hatchery flocks is particularly important. In

so far as possible a closed-flock breeding system should be carried on to reduce the chance of introducing diseases into the flock.

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CHAPTER 6

INCUBATION PRINCIPLES AND PRACTICE

Artificial incubation has practically replaced natural incubation as a method of securing chicks for laying-flock replacement purposes and for broiler and fryer production. During recent years about 90 per cent of all chickens raised annually on farms and commercial-egg-producing plants have been obtained as chicks from hatcheries. In addition, all the broilers produced commercially have been secured as chicks from hatcheries.

Incubator manufacturers have consistently improved the design of incubators from the standpoint of providing optimum conditions of incubation and with respect to efficiency of operation. At the same time, it is safe to say that for the country as a whole probably at least 25 per cent of the eggs set in incubators fail to produce chicks. This involves a great economic wastage. Part of it is due to infertility, but the greater part is due to factors affecting the hatchability of fertile eggs. A knowledge of the fundamental principles of successful artificial incubation is of the utmost importance, therefore, in increasing the efficiency of the hatchery industry.

The Length of the Incubation Period. The normal incubation period of the egg of the chicken is approximately 21 days, although chicks of the Leghorn and similar breeds usually hatch a few hours earlier than chicks of the heavier breeds, such as Plymouth Rock and Rhode Island Red, when the conditions of incubation for the eggs of the different breeds are identical.

In any given flock the largest eggs usually require a longer period of incubation than the smallest ones. The longer that hatching eggs are stored at room temperature before being incubated, the longer is the time usually required for incubation. Eggs of highly inbred birds sometimes require as many as 12 hr. longer for incubation than the eggs of birds of the same breed that are not inbred.

The development of the chick from the egg is a phenomenon of unusual interest, inasmuch as the various processes involved therein are closely related to the more important factors affecting hatching results. For instance, the development of the embryo during incubation is affected by such factors as the length of time that the fully formed egg is held in

the uterus before being laid, the position of the eggs during incubation, and the number of times that eggs are turned daily during the incubation period, as well as by the temperature, humidity, oxygen, and carbon-dioxide content of the atmosphere of the incubation chamber.

The development of the chicken embryo during the period of incubation is analogous to the development of the mammalian embryo during the gestation period. The mammalian embryo is developed entirely within its mother's body, whereas the chicken embryo, although starting its development within its mother's body, develops mostly outside.

Development before Laying. Approximately 3 hr. after the egg is fertilized in the oviduct, the germ spot, or reproductive cell, in the yolk

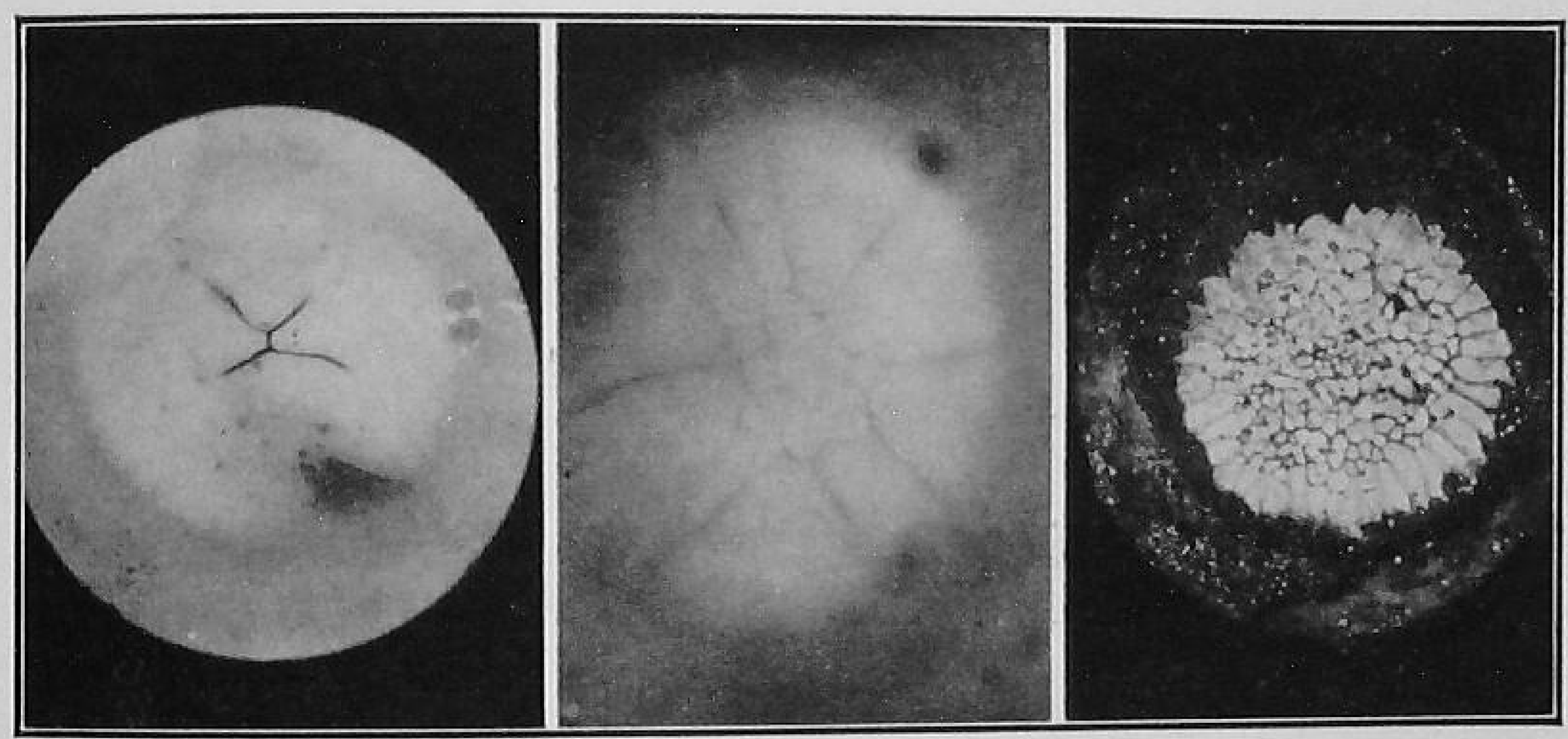

FIG. 76. Left, 4-cell stage of the germinal disc of a chicken egg removed from the isthmus section of the oviduct. Center, 16-cell stage of germinal disc of an egg removed from the uterus section of the oviduct. Right, many-cell stage of germinal disc in the late cleavage stage while the egg is in the uterus section of the oviduct: at least 256 cells are visible. (*M. W. Olsen*, 1942.)

divides into two cells, each of which divides into two cells (see Fig. 76). Cell division continues until a thin disc is formed. The cleavage process of the germinal disc continues and soon gives rise, through a process known as "gastrulation," to a structure having two layers of modified cells, the outer layer comprising the ectoderm and the inner layer the entoderm. At this stage of development the "blastoderm," as it is now called, is thinner and more transparent in its central portion, called the "area pellucida," and thicker around its margin, called the "area opaca," and is visible to the naked eye when a fertile egg is opened (see Fig. 77). The axis of the blastoderm lies at approximately right angles to the long axis of the egg. The cleavage process is arrested when the egg is laid but proceeds again when the egg is subjected to the proper temperature. If the temperature is much below 80°F., the development of the embryo is arrested, either partially or completely.

Development during Incubation. When the egg is placed under proper conditions of incubation, the blastoderm develops rapidly, the primitive streak appearing in the area pellucida during the first 12 hr. of incubation. It is in the area pellucida in which the embryo develops. The part of the blastoderm outside of the area pellucida gradually extends over the surface of the yolk and gives rise to the formation of the extraembryonic structures. The two-layered structure soon gives rise to

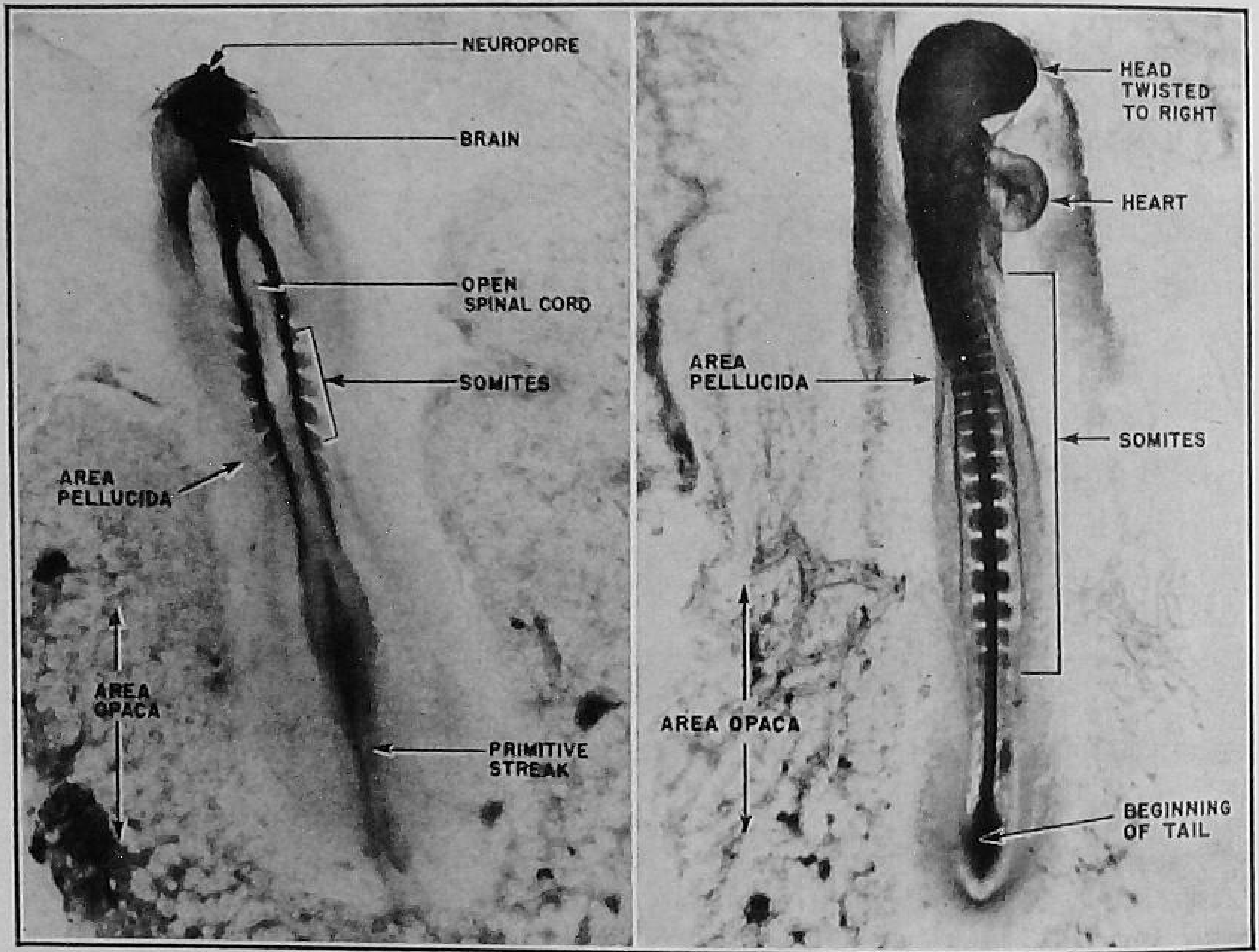

FIG. 77. Left, showing the principal morphological features of the embryo at 48 hr. Right, the embryo at 84 hr. Turkey embryos are represented here, but they serve as an excellent illustration of the early development of the chicken embryo. (*R. E. Phillips and C. S. Williams*, 1944.)

a three-layered structure, the mesoderm arising between the ectoderm and the entoderm.

The ectoderm gives rise to the skin, feathers, and other external features as well as the nervous system. The mesoderm gives rise to the bones, blood, muscles, and reproductive and excretory organs. The entoderm gives rise to the respiratory and secretory organs and the linings of the digestive tract.

The longitudinal axis of the embryo is indicated by the direction of the primitive streak (see Fig. 77). The primitive streak is a thickening of the ectoderm. Shortly after the embryo is 21 hr. old, pairs of vertical clefts appear in the mesoderm. These mesodermal segments or somites

(see Fig. 77) serve for some time as an index of embryonic development. For instance, at 24 hr. there are 5 somites; at 25 hr., 7 somites; and at 38 hr., 17 somites.

In an embryo 1 day old, the embryonic and extraembryonic regions of the blastoderm become more clearly defined. The head of the embryo is in a rapid process of growth and rises above the blastoderm. The extraembryonic regions are those regions of the blastoderm which do not become a part of the embryo proper. The area opaca adheres to the yolk beneath (see Fig. 77).

By the twenty-fifth hour the anterior neuropore (see Fig. 77) appears as an opening of neural tube, which has been formed by the closing of the ectodermal folds. The fore-brain has begun to form at the head end of the neural tube. The heart appears as a simple straight tube. From the second to about the eighth day, the rate of heart beat increases rapidly up to about 220 beats per minute and then gradually decreases during the rest of the incubation period until at hatching time the rate is about 200 beats per minute. The development of various embryonic structures progresses rapidly, especially the head and its parts. During the latter part of the second day, the upper part of the body of the embryo has twisted so that the left side lies flat upon the yolk.

At the end of the second day certain folds grow out and upward from the embryo, gradually approaching each other to form something of a roof over it. When these folds join, the two inner layers fuse and the two outer layers fuse so that the roof is double-walled. The inner wall surrounding the cavity enclosing the embryo is named the amnion, the outer wall is named the chorion. The cavity itself is called the amniotic cavity or more often simply amnion. It becomes filled with fluid, which provides protection against mechanical shock and prevents adhesions of the embryo through the action of muscle fibers which develop in the wall of the amnion.

During the third day of incubation, the embryo lies on its left side. By this time the allantois has developeda s an outgrowth from the posterior portion of the hind gut (see Fig. 78). As the embryo increases in size, the allantois extends farther and farther until its outer surface comes into close contact with the inner surface of the chorion. As the amount of albumen of the egg becomes reduced, the allantois is closely applied to the inner surface of the chorion, which in turn lies against the inner shell membrane. Thus, the allantois serves as a respiratory and excretory organ by means of which oxygen and carbon dioxide are received and discharged and excretions of the embryonic kidneys are received. The allantois absorbs nutrients from the albumen and calcium from the shell for the nourishment of the embryo.

The continued growth of the amnion results in the constriction of the opening from the intestine to the yolk sac, resulting in the formation of the yolk stalk, which ultimately comes into close contact with the allantoic stalk. As shown in Fig. 78, the inner lining of the yolk sac contains yolk-sac septa which absorb and digest yolk material for embryonic growth.

By the fifth day, as shown in Fig. 79, various external features are discernible. The curvature of the embryo is such that the head and tail approach each other. The brain consists of three parts, and the eye and the heart are plainly visible. Leg and wing buds mark the beginnings

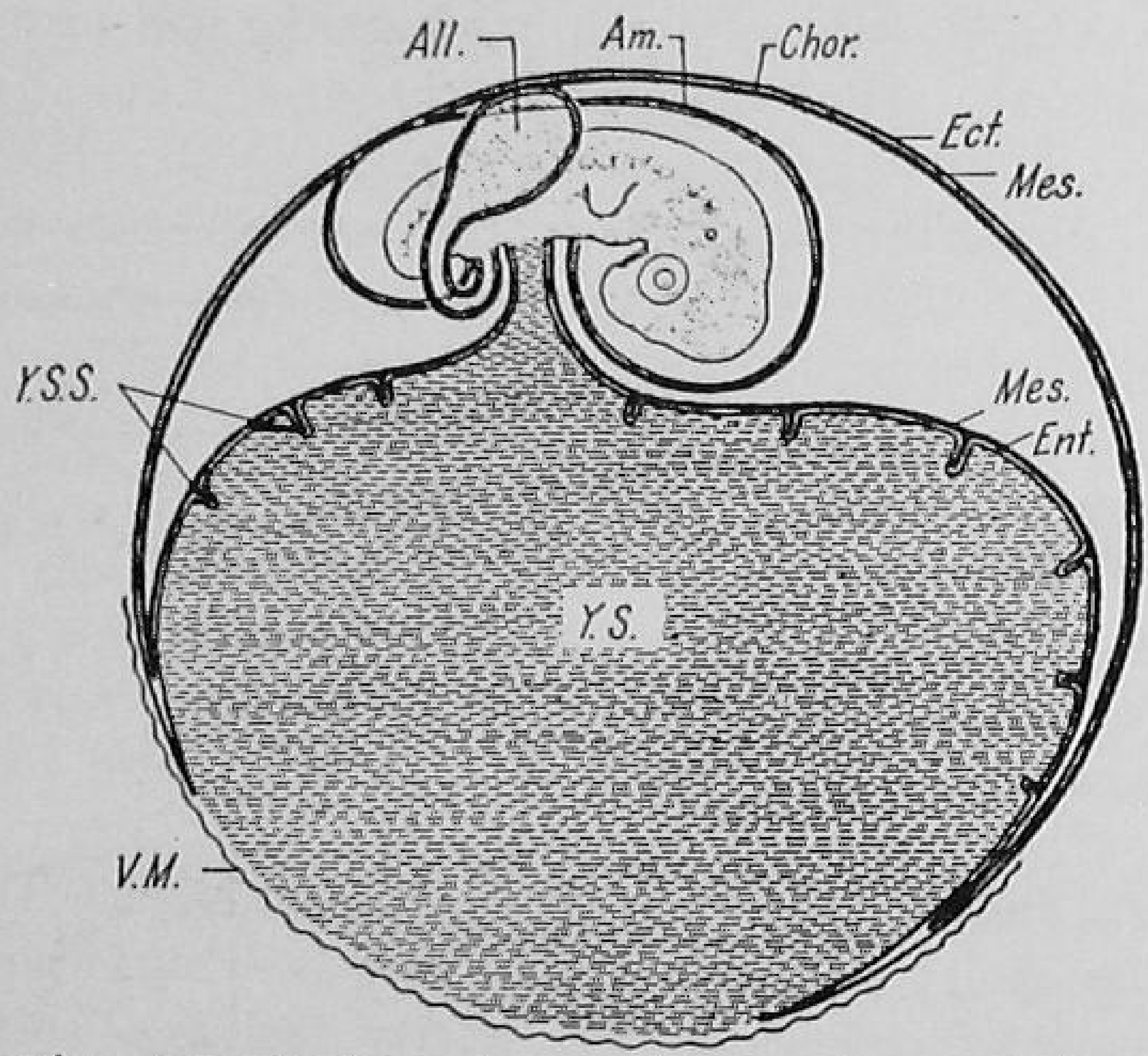

FIG. 78. Illustration of the chicken embryo and its membranes during the fourth day of incubation. All., allantois; Am., amnion; Chor., chorion; Ect., ectoderm; Ent., entoderm; Mes., mesoderm; V.M., vitelline membrane; Y.S., yolk sac; Y.S.S., yolk-sac septa. (*After Lillie in "The Development of the Chick" by permission Henry Holt and Company, Inc.*)

of legs and wings. Up to this time the chick embryo is very similar to the embryo of any mammal.

Figure 80 shows the extent to which the chicken embryo has developed at 8 and 11 days of incubation, respectively. Feather papillae in definite tracts and the beak make their appearance on the eighth day. By the twelfth day most of the albumen and some of the yolk material has been absorbed, as shown in Fig. 81. By the thirteenth day down covers most of the body, and nails and scales appear. From the fourteenth day on, the yolk serves as the chief source of nourishment for the embryo. The yolk sac enters the body of the embryo usually on the nineteenth or twentieth day, and the development of the chick is completed.

At Hatching Time. Up to hatching time respiration has taken place by means of the allantois; but when the beak is thrust into the air sac of

the egg, the lungs begin to function, and there is thus a marked change in the nature of the respiration. The beak, equipped with a horny cap on the upper mandible, pips a circle around the large end of the shell while the embryo revolves slowly within the shell. Two muscles in the neck of the chick are largely instrumental in enabling the chick to exert

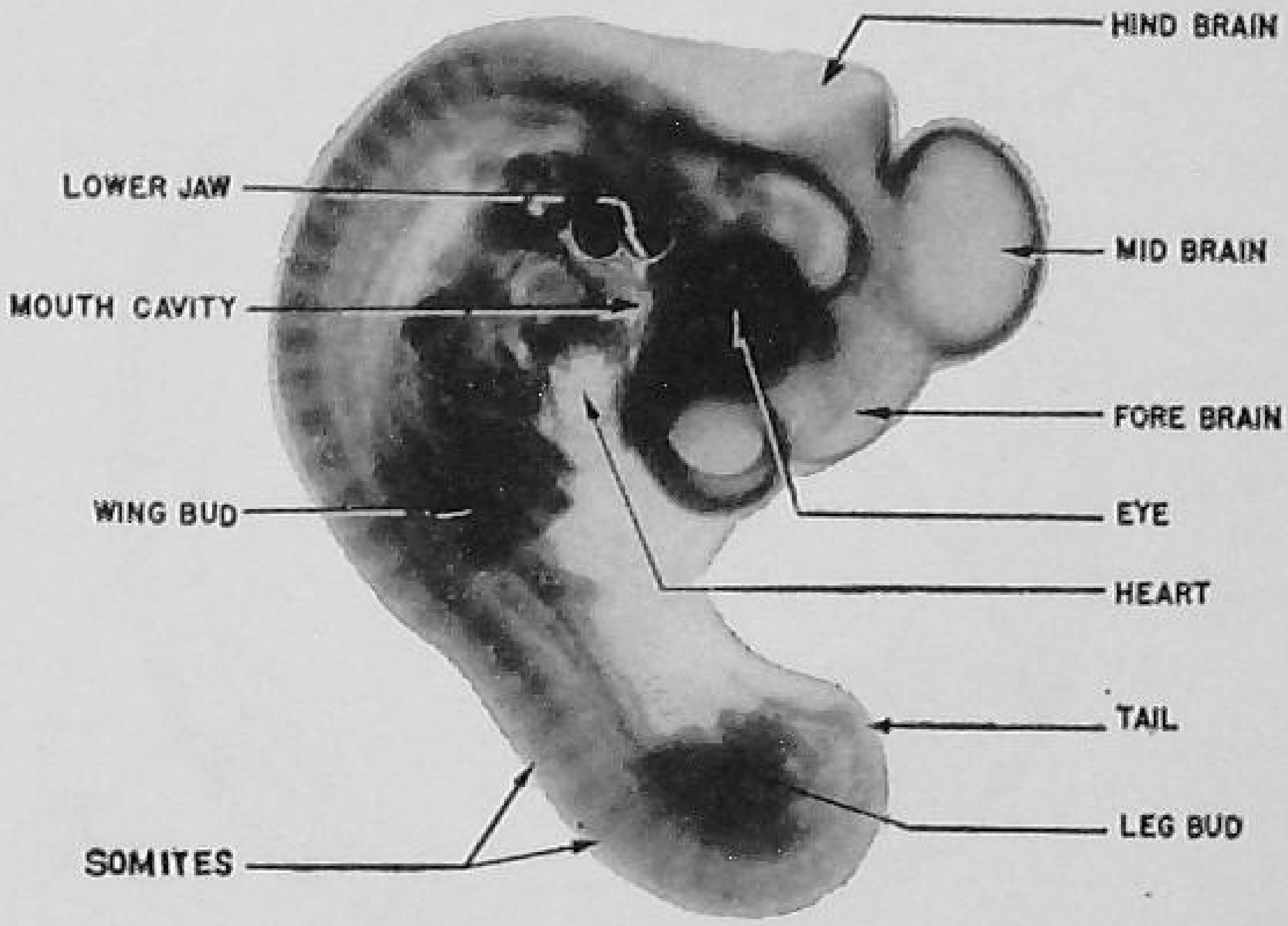

FIG. 79. The discernible morphological features of the embryo at 5 days of incubation. Although the illustration is that of a turkey embryo, the features of the chicken embryo at this age are practically identical. (*R. E. Phillips and C. S. Williams*, 1944.)

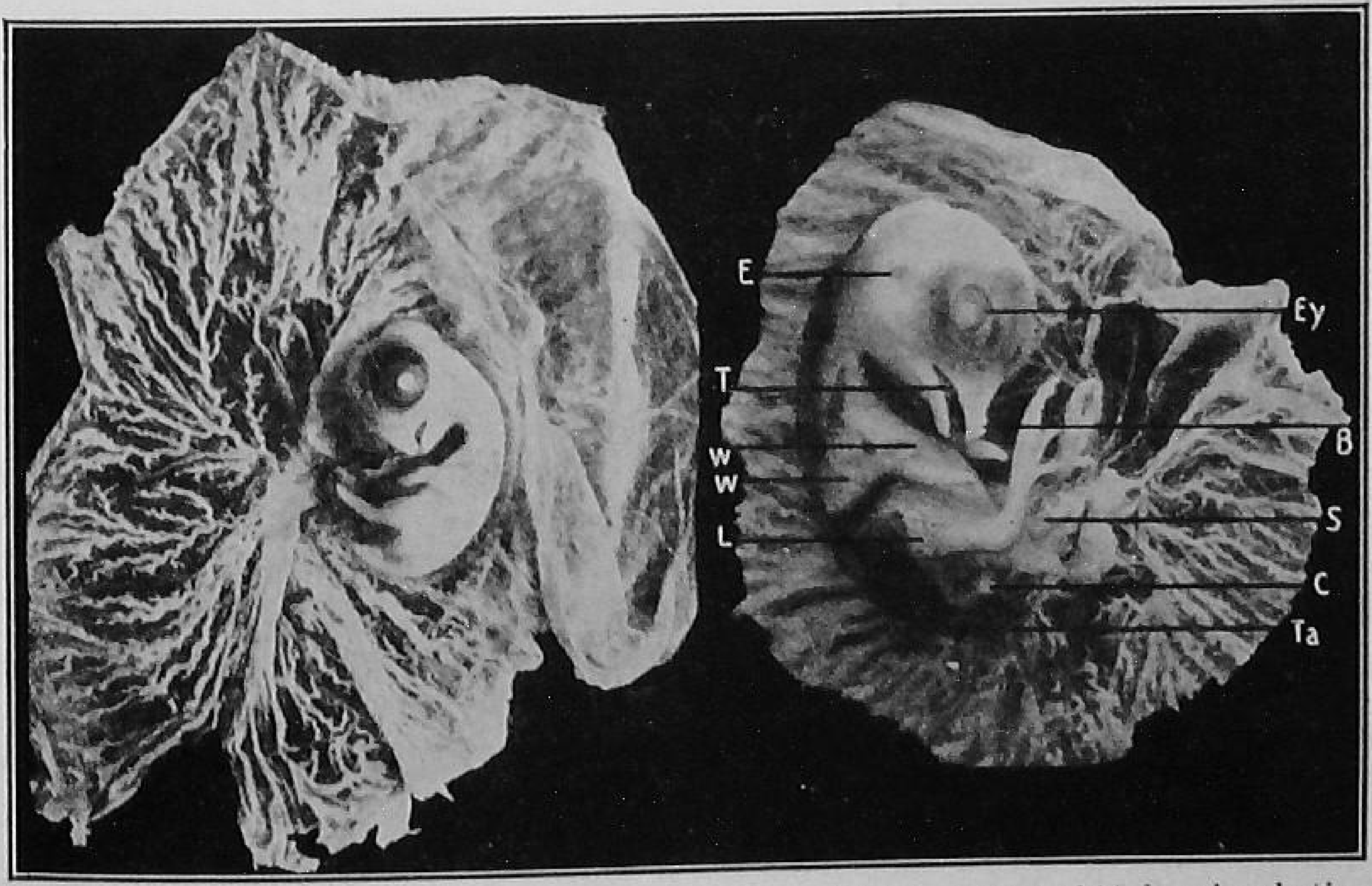

FIG. 80. Left, chicken embryo of 8 days incubation. Right, embryo of 11 days incubation seen from right side; (*B*) beak; (*C*) cloacal elevation; (*E*) ear; (*Ey*) eye; (*L*) leg with toes complete; (*S*) stalk of allantois; (*T*) tongue; (*Ta*) tail; (*W*) wing. (*After Evans.*)

enough pressure with its beak to break through the shell. The normal position of the chick at hatching time is described later in this chapter.

The Completed Chick. Twenty-one days have witnessed the transformation of the fertile egg into a fully formed chick, which leaves behind,

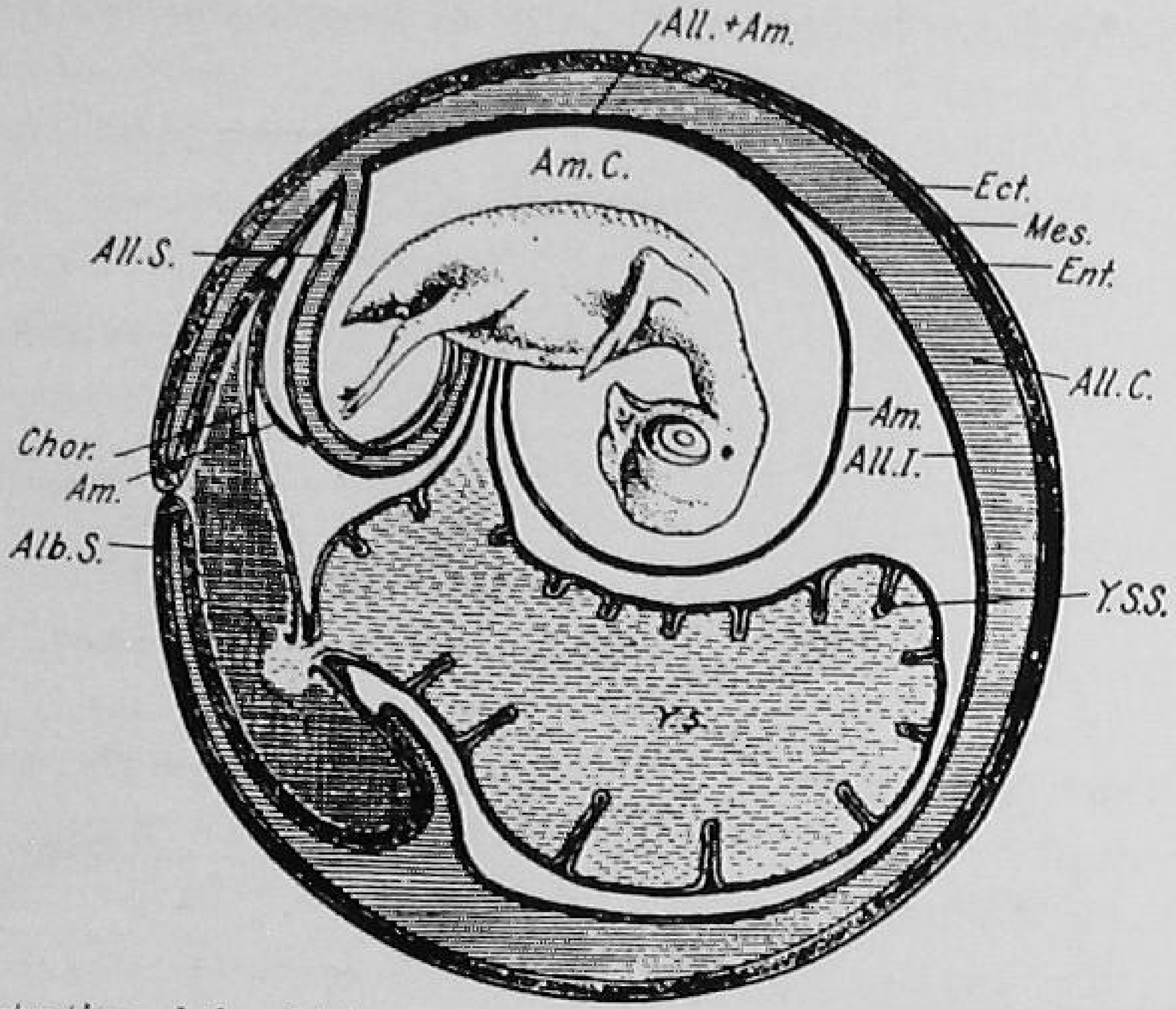

FIG. 81. Illustration of the chicken embryo and its membranes during the twelfth day of incubation. Alb. S., albumen sac; All., allantois; All. C., allantoic cavity; All. I., inner wall of allantois; All. S., allantoic stalk; Am., amnion; Am. C., amniotic cavity; Chor., chorion; Ect., ectoderm; Ent., entoderm; Mes., mesoderm; Y.S., yolk sac; Y.S.S., yolk-sac septa. (*After Lillie in "The Development of the Chick" by permission Henry Holt and Company, Inc.*)

as remnants, the shell, the shell membranes, and the membranes of the allantois and amnion.

THE PHYSIOLOGY OF EMBRYO DEVELOPMENT

During the incubation of fertile eggs, the white increases in viscosity, while, in the yolk, viscosity decreases rapidly till the fifth day, after which it rises until the end of incubation. The yolk gains in water at the expense of the white.

At the beginning of incubation, the yolk is acid; but as incubation proceeds, the yolk becomes alkaline, with a sudden temporary drop at the sixteenth day. The white reaches its highest peak of alkalinity at about 2 days of incubation, thereafter gradually changing to become neutral. The trend toward acidity on the part of the white is of significance in relation to the increased production of carbon dioxide by the embryo as development proceeds.

The Respiration of the Developing Embryo. It has long since been determined that the developing embryo gives off carbon dioxide and takes in oxygen. The embryo respires long before the lungs are developed.

The air space, usually formed in the large end of the egg, serves an important function in respiration. The embryo will develop normally if the entire egg, except the upper part containing the air space, is coated with a varnish or with water glass. In one case coating the large end of the egg with paraffin, in eggs incubated large end up, lowered the percentage of chicks hatched and increased the percentage of chicks with their heads in the small end of the egg.

Increase in Carbon-dioxide Elimination. The carbon dioxide (CO_2) in the air space of the egg increases only four or five times during incubation, whereas the carbon dioxide produced by the embryo increases about forty times. In this connection it is interesting to note that the shell and the shell membrane above the air space become progressively more permeable as embryonic development proceeds. The elimination of carbon dioxide decreases from the first to about the third day of incubation, after which the amount eliminated is proportional to the weight of the embryo.

Oxygen Requirements Increase. As the embryo develops, the amount of oxygen required increases. The ratio of the carbon dioxide given off to oxygen consumed is known as the "respiratory quotient." For the first 2 days of incubation the respiratory quotient is about 1.00, after which it declines to about 0.70 on the tenth day, thereafter remaining constant.

An insufficient supply of oxygen either kills the embryo in the early stages of development or produces abnormal chicks. The atmosphere ordinarily contains approximately 21 per cent of oxygen, and the results of research have shown that the atmosphere of the egg chamber should contain 21 per cent of oxygen in order to secure best results in hatching.

The Metabolism of the Developing Embryo. The egg is composed of carbohydrates, fat, protein, and minerals, and the shell is composed largely of calcium. These substances are utilized by the embryo at different rates during its development.

The developing embryo secures its energy from three successive sources: carbohydrates; then proteins, and, lastly, fat. These elements serve as sources of energy.

Carbohydrate metabolism has its chief importance at the beginning of development, when the various organs of the embryo are taking shape. There appears to be a close correlation between the utilization of sugar by the embryo and its respiratory quotient during the first 5 days.

The total glucose of the whole egg decreases up till the seventh day, then increases until the eleventh, when it again decreases. This increase in carbohydrates between the seventh and the eleventh day corresponds to a loss of fats, which do not suffer combustion but are transformed in the embryo into carbohydrates.

During the last week of embryonic development there is a certain current of protein into the yolk, and this is also true of water. Enzymes break down the proteins and prepare them for embryonic nourishment. Uric acid accumulates up to the time of hatching, indicating the continuous oxidation of protein.

Fat is the most important source of energy. The metabolism of fat takes place principally after the eleventh day. The rate of the metabolism of fat is apparently controlled by the increase in the weight of the liver, which is very small up to the fourteenth day, after which it rapidly increases in size. The curve of consumed fat is quite similar to the curve of the rate of the growth of the embryo.

The greatest changes in phosphorus metabolism occur after the fifteenth day of incubation and apparently phosphorus utilization by the embryo is associated with the calcification of bone. Concerning the utilization of calcium, all investigators report a large increase of calcium in the embryo and a loss of it from the shell, the calcium in the shell being broken down more readily in the presence of carbon dioxide. Approximately 75 per cent of the calcium of the newly hatched chick comes from the shell during the process of incubation.

Although the developing embryo obtains its energy, for the most part, first from the carbohydrates, then from the proteins, and lastly from the fats, the embryo is able to store about 98 per cent of the proteins available, about 82 per cent of the carbohydrates, and about 43 per cent of the fat. The efficiency of the metabolism of the three elements combined for the whole of the embryo's development is about 68 per cent.

Embryo Mortality and Its Causes. In some flocks a few hens may be observed that have a 100 per cent hatching record for the entire breeding season. In such cases three important observations are worthy of note: (1) Hens with a hatchability record of 100 per cent are superior individuals which possess the genetic constitution for high hatchability; (2) the conditions of incubation were obviously satisfactory; (3) the eggs laid by the other members of the flock must have been deficient in certain respects which resulted in the death of the embryos sometime during the incubation period. That hens differ genetically in their ability to produce eggs of good hatching quality has already been demonstrated in a previous chapter. Certain it is that the genetic constitution of the breeding stock is an important factor in relation to embryo mortality among the eggs they produce.

That the diet which the breeding stock receives sometimes increases embryo mortality is demonstrated in a later chapter.

Faulty methods of incubation, of course, usually result in relatively high embryo mortality.

On the other hand, among the eggs laid by practically all flocks that have been bred and fed for high hatchability and where satisfactory conditions of incubation prevail, there is usually some embryo mortality. As a matter of fact, a hatchability of 85 per cent of all eggs set is regarded as very satisfactory, showing that under what may be termed the best of conditions embryo mortality amounts to 15 per cent.

Critical Periods in Embryo Development. It has been found that approximately 65 per cent of the total embryo mortality occurs, for the most part, at two periods of incubation. The curves in Fig. 82 show that the first period of relatively high embryo mortality includes the second, third, and fourth days of incubation, and the second period from the

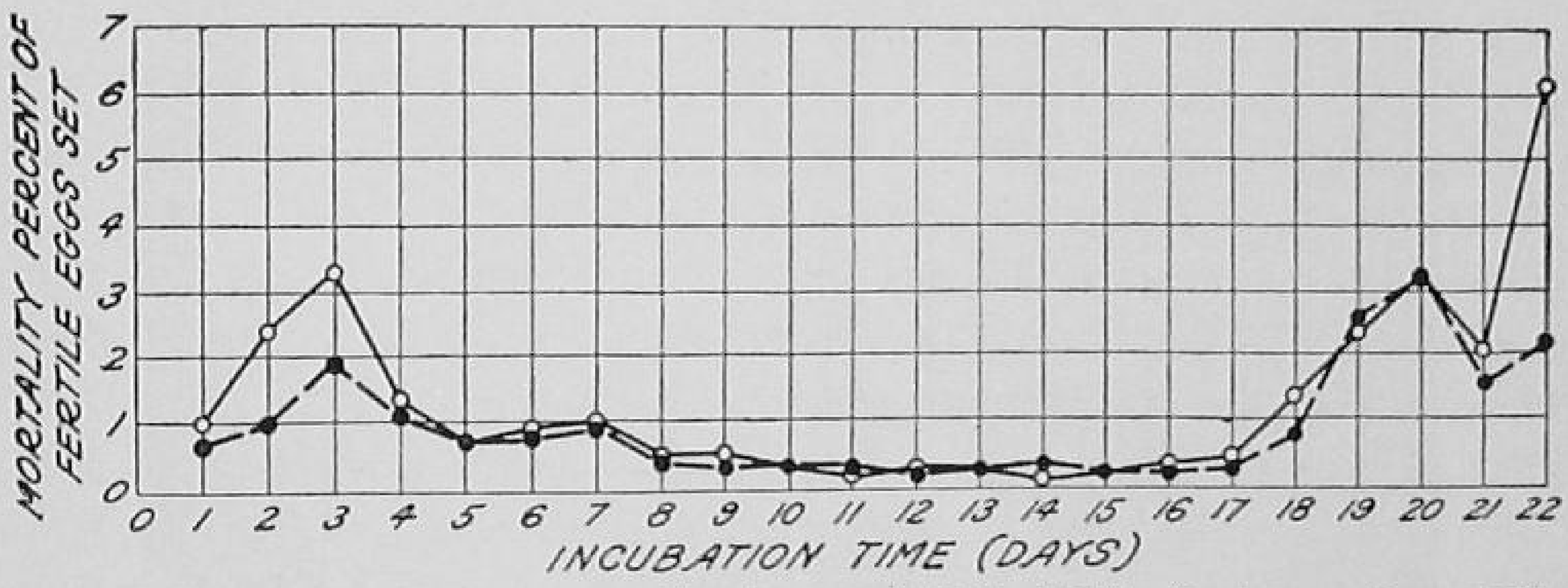

FIG. 82. Showing embryonic mortality in eggs laid by White Leghorns, ○, and Rhode Island Reds, ●. (*Byerly, Knox, and Jull.*)

eighteenth to the twenty-first days. Apparently, these two periods of relatively high embryo mortality are associated with certain physiological processes that take place during embryo development.

It is interesting to note, for instance, that the rate of growth and gross form development change rapidly during the early stages of incubation, while the concentration of solids and chemical differentiation change mostly during the last half of the incubation period. The fact that lactic-acid production reaches a peak on the fourth day may also have some bearing on early embryo mortality.

There are apparently four cycles of growth during embryo development. The first cycle of growth continues from the first to about the fourth day, the second cycle from the fourth to about the seventh day, the third from the seventh to about the seventeenth day, the fourth from the seventeenth to about the nineteenth day.

Embryo Position and Mortality. The normal position of the embryo at hatching time is with the head toward the larger end of the egg with the neck bent sufficiently to bring the head to the right side of the body and the beak under the right wing, the tip of the beak pointing toward

the air cell; the legs are on the ventral side of the embryo with the feet folded so that the toes reach the head (see Fig. 83).

Occasionally, however, embryos are observed that deviate from the normal position. Some of the malpositions are as follows: (1) The head extends down the ventral surface of the body and is buried between the thighs; (2) the position of the chick is completely reversed so that the head is in the small end of the egg; (3) the head is toward the large end of the egg but is bent to the left instead of to the right; (4) the chick is rotated in such a way that the beak is not directed toward the air cell;

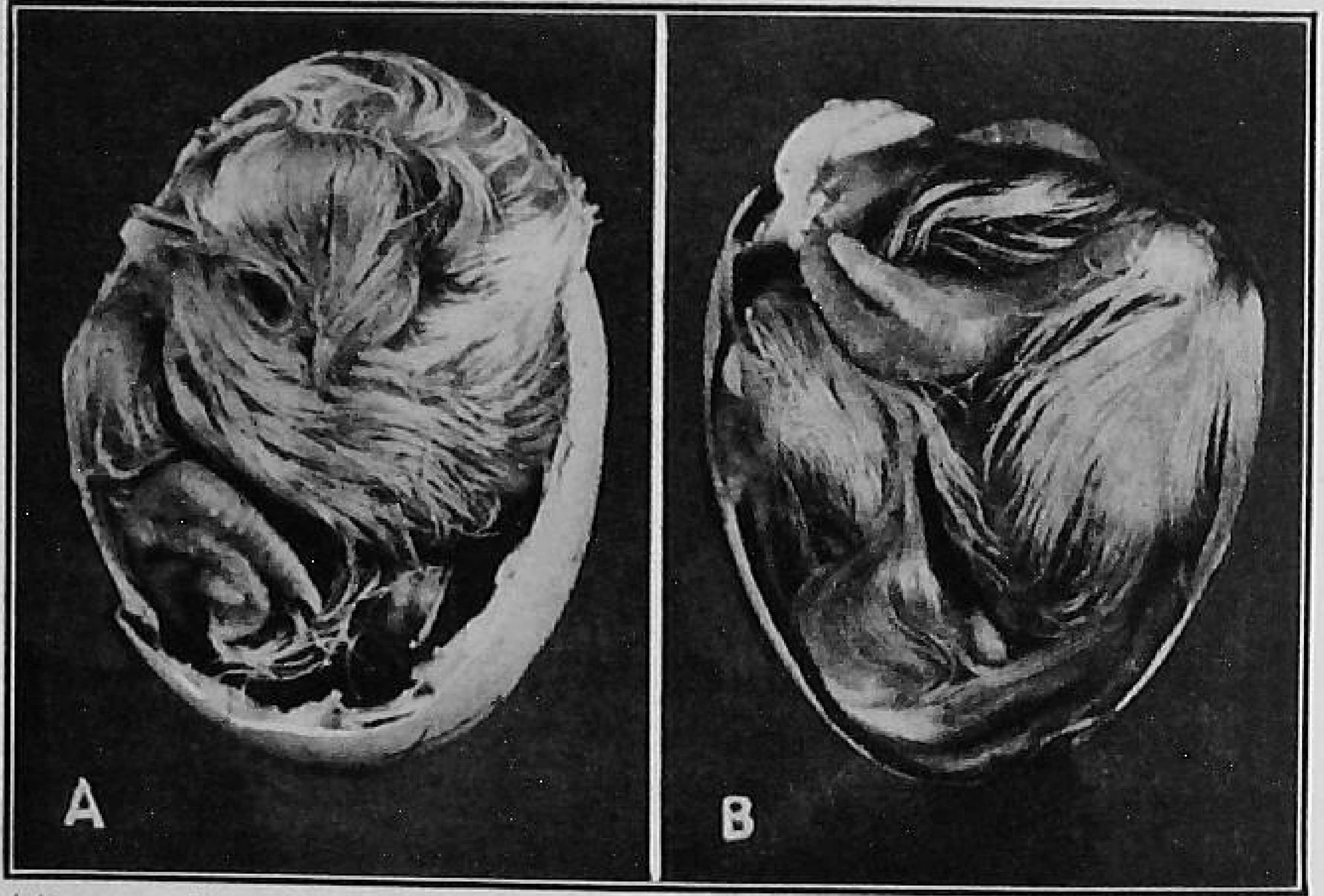

FIG. 83. (*A*) normal position of chick at hatching time; the head is under the right wing and the beak points toward the air cell. (*B*) the chick is in a completely reversed position, the head being in the small end of the egg. (*Cavers and Hutt.*)

(5) the feet are over the head; (6) the beak is above the right wing instead of beneath it. Some of these malpositions are hereditary in nature and some are influenced by conditions of incubation. Under normal conditions of incubation, including frequent turning of eggs, malpositions probably do not materially reduce the hatchability of eggs produced by most flocks. On the other hand, one or more of these malpositions might be of considerable concern to a pedigree-poultry breeder. A large portion of the dead-in-shell embryos is apparently due to defective embryos and those in which development has been delayed rather than to malpositions.

PHYSICAL FACTORS GOVERNING SUCCESSFUL INCUBATION

The more fundamental aspects of the structural and physiological development of the embryo having been discussed, it now remains to consider the optimum conditions of incubation that should prevail in

order to secure the largest possible number of good chicks in proportion to the number of eggs incubated.

The more important conditions of incubation affecting hatching results include: (1) position and turning of eggs; (2) temperature requirements; (3) ventilation requirements, particularly with respect to the elimination of carbon dioxide and the available supply of oxygen; and (4) humidity requirements.

Position and Turning of Eggs. In artificial incubation the eggs are placed on the trays in an oblique position large end up for two reasons: (1) It has been observed that eggs incubated large end up are much more inclined to have the embryo develop with its head in the large end of the egg than when the eggs are placed small end up, and (2) placing the eggs large end up rather than flat allows more eggs to be incubated at one setting.

Frequent turning of the eggs during incubation is desirable in order to prevent the embryo from adhering to the shell membrane, especially in the early stages of incubation, and to prevent any adhesion between yolk and allantois in the later stages of incubation. The results of research at a number of experiment stations show clearly that turning eggs as many as eight times daily gives better results, on the average, than turning twice daily. It has also been shown that it is much more important to turn eggs frequently during the first half of the incubation period than during the second half. From a practical standpoint, the turning should be done as early as possible in the morning and as late as possible at night, with several turnings between times during the first half of the incubation period.

Temperature Requirements. Because of the relative importance of proper temperature in the incubation of eggs, much research has been conducted for the purpose of determining the optimum temperature and the effect of variations in temperature in the artificial incubation of eggs. A review of the literature reveals the fact, however, that numerous research workers apparently overlooked the fact that the optimum temperature for successful artificial incubation is to some extent dependent upon the humidity of the air in the egg chamber and upon the rate of air circulation.

Since many of the results on incubation temperatures are reported in terms of degrees centigrade, it is advisable to mention here, for the sake of those consulting such results, that the Fahrenheit temperature is obtained by multiplying the Centigrade temperature by 1.8 and adding 32 to the product. Thus, 40°C. = 104°F. In this book incubation temperatures are discussed in terms of degrees Fahrenheit.

Incubators of many different types have been devised so that it has

become necessary to determine optimum temperatures for incubation purposes in the different types. From the standpoint of temperature requirements, the various types of incubators may be divided into two groups: (1) incubators in which warm air is conducted to the top of the egg chamber and diffuses downward over the eggs or the eggs are heated by radiation from the heat supplied by pipes of warm water; (2) incubators in which the egg chamber is heated by mechanically forced circulation of air which is heated by electrical elements.

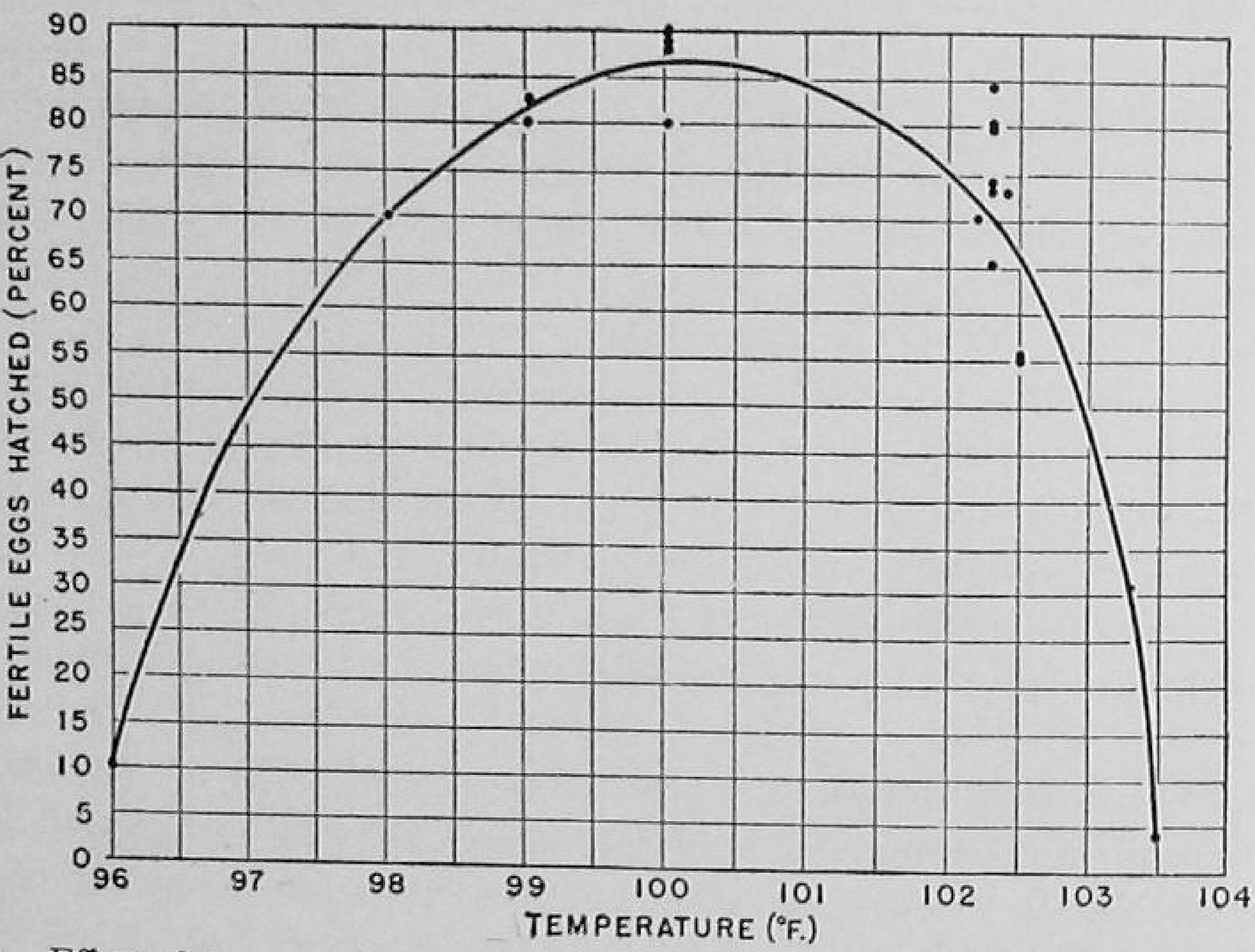

FIG. 84. Effect of temperature on percentage of fertile eggs hatched (relative humidity, 60 per cent; oxygen, 21 per cent; carbon dioxide, below 0.5 per cent). (*H. G. Barott.*)

With respect to the first group of incubators the general conclusion of the numerous lines of research work is that during the first 2 weeks of the incubation period the temperature on a level with the top of the eggs should be 101.5°F. and that during the last week the temperature at the same location should be 102.5°F.

The results of research on the temperature requirements in incubators heated by mechanically forced circulation of air indicate that approximately 100°F. is the optimum temperature. One series of tests was conducted at temperatures of 96, 98, 99, 100, 102, and 103.5°, the relative humidity in all tests being kept at 60 per cent, the concentration of oxygen at 21 per cent, and the concentration of carbon dioxide below 0.5 per cent. In all tests the air movement past the eggs was approximately 12 cm. per min., and it should be observed the temperature at the bottom and the top of the egg was the same. The best hatches were

secured at a temperature of 100°F. Deviations in temperature above and below 100°F. resulted in lowered hatches until at 96 and 103.5°, respectively, nearly all the embryos died in the shell. Many modern types of incubators are operated at 99.5 or 99.75°F.

It remains to be determined whether or not better hatching results might be secured if temperatures of 99.5°F. for the first half and 100.5°F. for the second half of the incubation period were maintained or some other temperatures for different periods of incubation than maintaining a temperature of 100°F. throughout the entire hatching period.

Excessively high temperatures give rise to an increase in the rate of growth of the embryo, resulting in an increase in the liberation of carbon dioxide, and there is a marked tendency for the embryos to assume abnormal positions within the egg. If relatively high temperatures are maintained for too long a period, embryo mortality is certain to be excessive.

Excessively low temperatures cause a retardation in embryo development, accompanied by a diminution of carbon-dioxide output. Especially during the first 2 or 3 days of the incubation period are excessively low temperatures liable to cause the death of the embryo.

The practice of cooling eggs for a few minutes each day of incubation, although practiced to a considerable extent for several years, has been found to be inadvisable.

Ventilation Requirements. The proper ventilation of the incubator chamber during the incubation of eggs is necessary because as the embryo develops it requires oxygen, and it liberates more carbon dioxide, most of which must be removed from the incubator chamber.

The embryo breathes long before the formation of lungs, the oxygen absorbed and the carbon dioxide eliminated passing through the porous shell. In one series of experiments, it was found that the best hatches were obtained when the carbon-dioxide content of the egg chamber was kept at 0.5 per cent throughout the period of incubation. It was further found that the decrease in the hatch was proportional to the increase in the carbon-dioxide content of the egg chamber. It is obvious, therefore, that the ventilation of the incubator chamber must be such that the carbon dioxide eliminated by the embryos will be removed fast enough so that the carbon-dioxide content of the atmosphere of the egg chamber does not exceed 0.5 per cent.

Since the developing embryo requires oxygen, it is obvious that the ventilating device of the incubator must be so designed as to supply adequate amounts throughout the period of incubation. The atmosphere of the egg chamber should contain 21 per cent of oxygen, which is the oxygen content of normal air. In one case it was found that each per

cent decrease below 21 per cent in the oxygen content of the atmosphere of the egg chamber reduced the hatch by approximately 5 per cent. For each per cent increase in the oxygen concentration the hatch was reduced approximately 1 per cent. Therefore, a deficiency in oxygen supply is relatively much more harmful than an excess. At high altitudes, it has been found that hatchability is increased by adding oxygen to the atmosphere of the egg chamber. Adding oxygen during the 3-week incubation period gave the best results, followed by adding oxygen during the first and third weeks.

Humidity Requirements. During incubation the eggs lose weight, a large part of which is due to loss in water content. The amount of water

FIG. 85. Effect of oxygen during incubation on percentage of fertile eggs hatched (temperature, 99°F.; relative humidity, 70 per cent; carbon dioxide, below 0.5 per cent). (*H. G. Barott.*)

eliminated has been found to be very largely proportional to the humidity of the atmosphere of the egg chamber.

Research work has demonstrated that it is the relative rather than the absolute humidity of the atmosphere of the egg chamber that affects hatching results. Relative humidity refers to the ratio between the amount of water vapor actually contained in the atmosphere at a given temperature and the amount of vapor the atmosphere is capable of holding at the same temperature. It is well known, of course, that the capacity of air to absorb and hold moisture increases as its temperature rises; at 50°F., 1,000 cu. ft. of air is capable of holding 0.587 lb. of water vapor, whereas at 100° the same amount of air is capable of holding 2.851 lb. of water vapor. If it should be found that at 100°, 1,000 cu. ft. of air contains 1.711 lb. of water vapor, which is 60 per cent of what it is capable of holding at that temperature, the relative humidity would be 60 per cent.

Research work has demonstrated that the best hatches are obtained when the relative humidity of the atmosphere of the egg chamber is maintained at near 60 per cent.

The relative humidity of the egg chamber is determined by reading

the temperature of the dry- and wet-bulb thermometers. When the atmosphere in the egg chamber is relatively dry, evaporation from the wet bulb is increased, thus lowering the temperature of the wet bulb as compared with the dry-bulb temperature.

Most modern incubators are provided with a separate hatching compartment to which the eggs are transferred on the eighteenth day. From the eighteenth to the twenty-first days the relative humidity of the atmosphere of the hatcher should be kept at about 70 per cent.

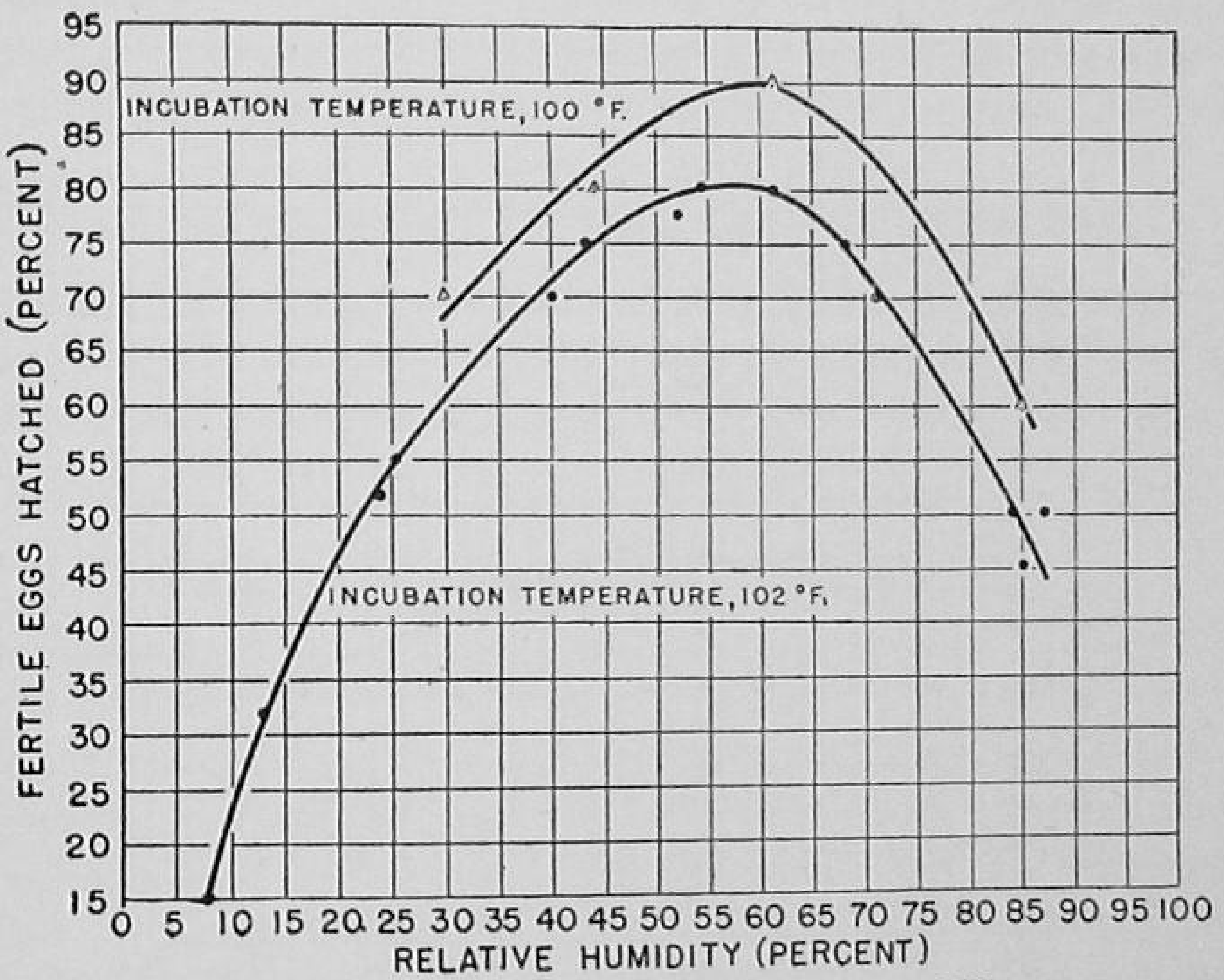

FIG. 86. Effect of relative humidity during incubation at two different temperatures on percentage of fertile eggs hatched (oxygen, 21 per cent; carbon dioxide, 0.5 per cent). (*H. G. Barott.*)

Optimum Conditions for Incubation. The optimum conditions for the successful incubation of eggs may be summarized as follows: (1) For section-type incubators, which do not have mechanically forced circulation of the air in the egg chamber, the temperature on a level with the top of the eggs should be 101.5° during the first half of the incubation period and 102.5° during the last half of the incubation period; (2) for cabinet-type incubators, equipped for the mechanically forced circulation of air, the temperature should be 100.0°, or slightly under, throughout the period of incubation; (3) for all types of incubators the ventilation should be such as to maintain an atmosphere in the egg chamber containing 21 per cent oxygen and not over 0.5 per cent carbon dioxide; (4) in all incubators a relative humidity of about 60 per cent should be maintained in the atmosphere of the egg chamber through the period of incubation.

The successful incubation of eggs to produce the largest possible number of good chicks in proportion to the number of eggs incubated depends not only upon providing optimum conditions of incubation but also upon the selection and care of the eggs intended for incubation. Granted, however, that the selection and care of the hatching eggs have been such that the best possible hatching results can be secured, it is still important to bear in mind that certain things are necessary besides merely providing optimum physical conditions of incubation in the incubator in order to secure satisfactory hatches year after year. Such factors as the location of the incubator, its proper disinfection, and the proper care of incubator equipment all have a bearing upon successful incubation practice.

THE SELECTION AND CARE OF HATCHING EGGS

The careful selection of eggs for hatching purposes is a very important matter because the kind of eggs incubated determines, to a large extent, the quality of chicks hatched. Fertile eggs of good hatching quality are

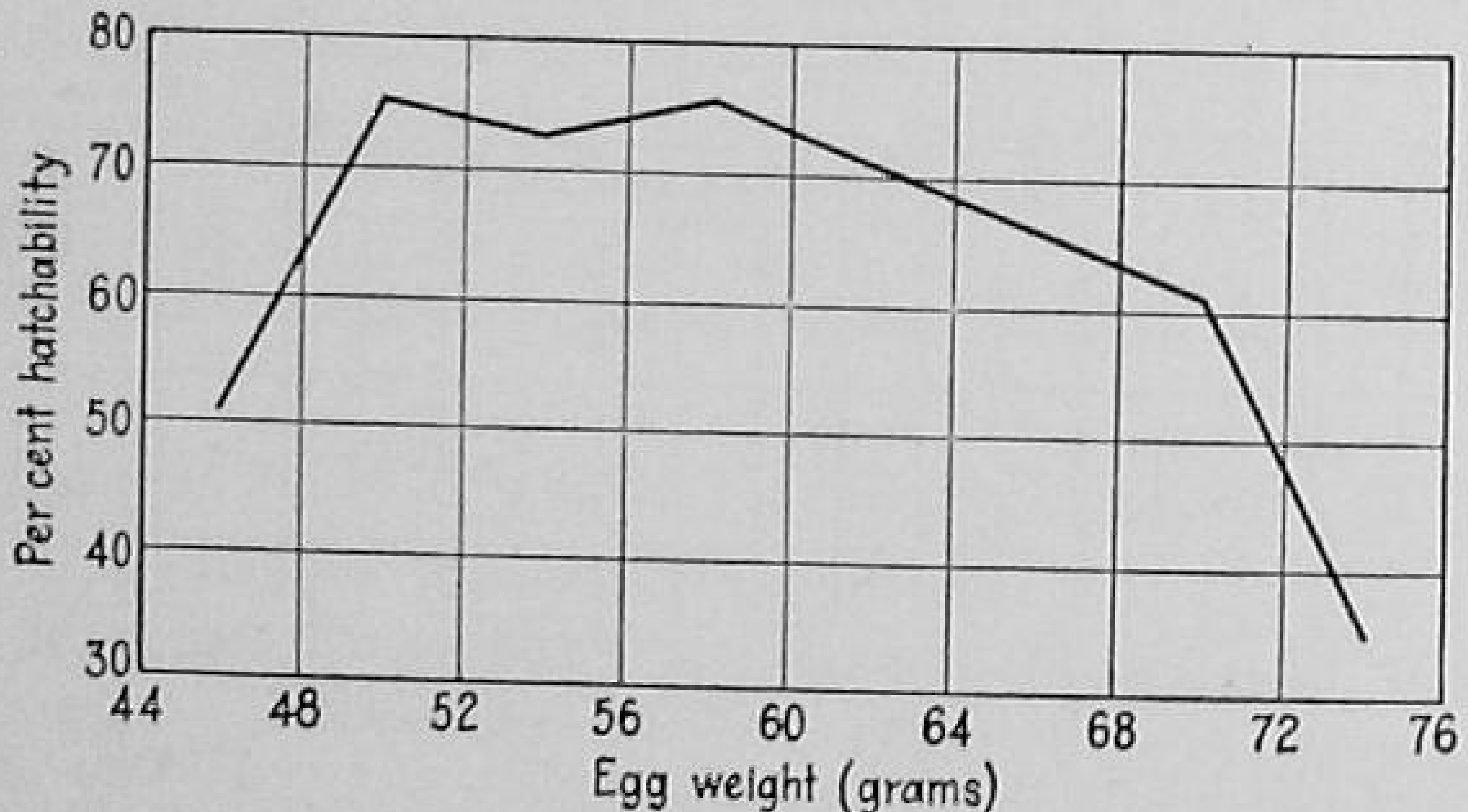

Fig. 87. Showing relationship between average egg weight per bird and hatchability, eggs laid by 367 hens during one hatching season. (*A. B. Godfrey.*)

necessary for good hatches. All eggs for hatching should be uniform in shape and size and sound in shell. Neither the size, shape, nor color of eggs has any influence on the sex ratio of chicks hatched therefrom.

Egg Size. The size of the eggs used for hatching is important because there is a high correlation between the size of eggs used and the size of chicks hatched. Furthermore, the continued use of small eggs for hatching purposes would soon result in reducing the average size of the birds in a flock, as well as decrease in the size of eggs shipped to market. It is desirable to use eggs approximating 2 oz. or 56.7 g. each. Eggs approximating standard market size hatch better than small eggs and very much better than very large eggs (see Fig. 87). Eggs that are large in proportion to the size of the hen producing them tend to hatch poorly.

Eggs in which the proportion of white to yolk is about 2:1 usually hatch better than eggs having wider or narrower ratios.

Shell Color. In the case of varieties of chickens that lay white-shelled eggs, all eggs used for incubation should be free from tints, except for the first few tinted eggs laid at sexual maturity. This is an economic factor that has caused considerable loss in marketing eggs produced by some strains of White Leghorns. Birds that continue to lay tinted eggs should be removed from the breeding flock.

In general-purpose breeds there seems to be a tendency for eggs with dark-brown shells to hatch better than eggs with light-brown shells, as shown in Table 28.

TABLE 28. PER CENT HATCH OF EGGS OF NEW HAMPSHIRES THAT LAID LIGHT-BROWN, MEDIUM-BROWN, AND DARK-BROWN EGGS, RESPECTIVELY
(E. M. Funk and J. F. Forward, 1949)

Eggs laid	No. of hens	Average egg production during hatching period	Chicks hatched, per cent
Light brown	12	90.8	56.7
Medium brown	134	95.9	68.3
Dark brown	60	82.1	76.9

It has been demonstrated that, as compared with light-brown eggs, dark-brown eggs usually have thicker shells which contain relatively more calcium, and dark-brown eggs also have a somewhat higher specific gravity. The darker color and greater thickness of shell are apparently due to the fact that such eggs spend a relatively longer time in the uterus than do light-brown eggs. Just why light-brown eggs with thinner shells hatch less well than dark-brown eggs is not clear, although the relative amount of water lost from the egg during incubation or the amount of calcium in the shell may be a factor. At any rate, color of shell, thickness of shell, and specific gravity are traits of individual hens just as is egg shape.

Cracked Shells and Tremulous Air Cells. All eggs should be tested for cracked shells, and this can be done quite readily by tapping two eggs together. If there is a resonant sound, both eggs are sound in shell; but if there is a dull sound, one of the eggs is cracked and should not be used for incubation. Care should be exercised in shipping or delivering eggs to a hatchery to avoid excessive shaking which sometimes results in a condition known as "tremulous air cells," a condition that tends to lower hatchability.

Since the practice of shipping hatching eggs by airplane has increased

considerably during recent years, it is interesting to note that experimental tests have demonstrated that reduced air pressure corresponding to an altitude of 78,000 ft. apparently has no detrimental effect on hatchability.

Soiled Eggs. Soiled eggs may be washed without their hatchability being impaired, providing the solution in which they are washed is some-

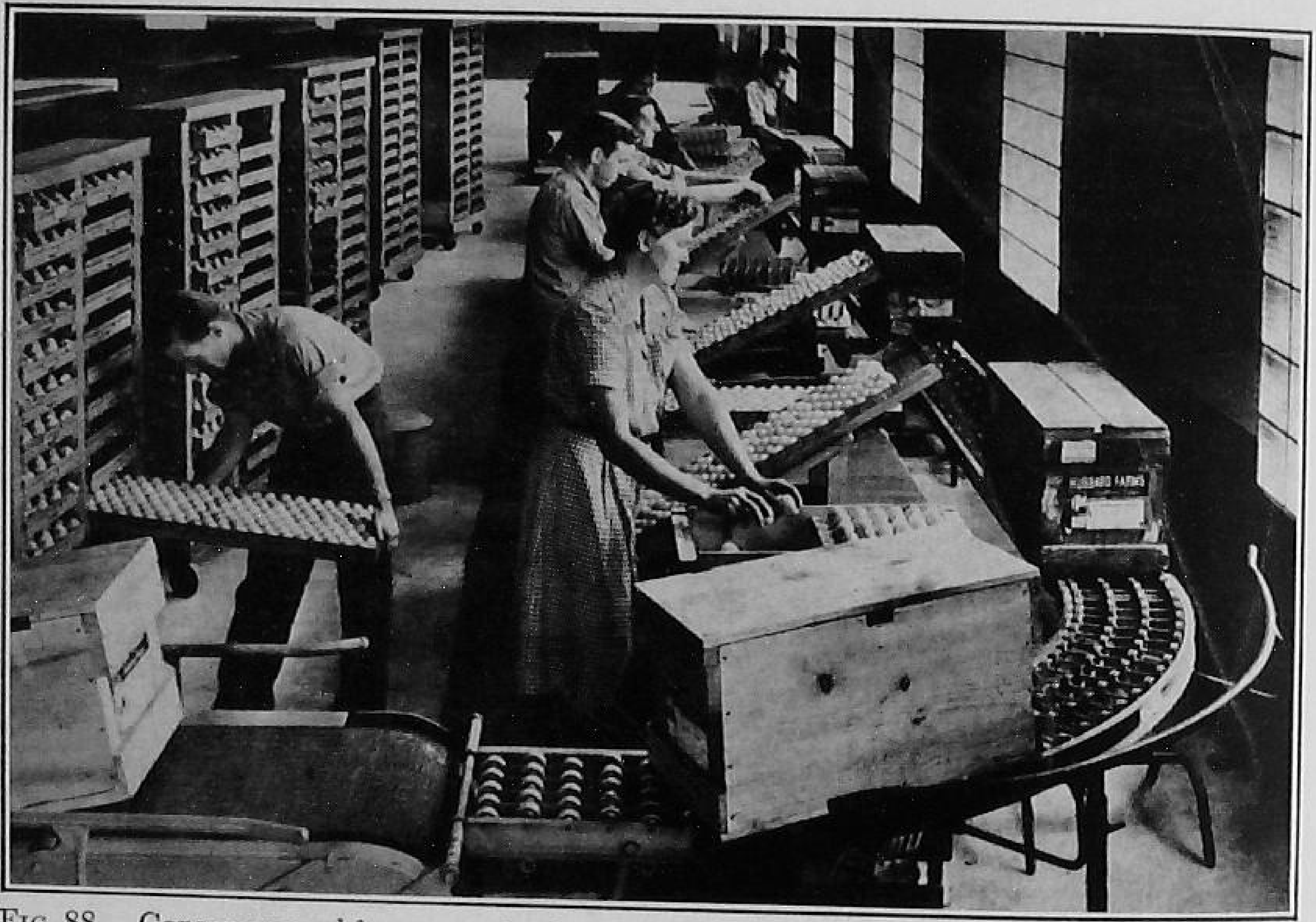

FIG. 88. Conveyor used for conveying hatching eggs from receiving room of hatchery to the incubator room where the eggs are sorted and trayed. (*Hubbard Farms, Inc.*)

what warmer than the eggs. The temperature of the water or solution should be about 160°F. Satisfactory results have been secured by using warm water, a 1 per cent lye water solution, a 0.5 per cent solution of formalin, or a 0.38 per cent Roccal solution (10 per cent quaternary ammonium compound), results with Roccal being given in Table 29.

TABLE 29. PER CENT HATCH OF CLEAN, UNWASHED EGGS AND OF SOILED EGGS WASHED WITH ROCCAL
(E. M. Funk and J. F. Forward, 1949)

Kind of eggs	No. of eggs set	Chicks hatched, per cent
Clean, unwashed...........	18,081	69.9
Soiled, washed.............	1,215	69.1

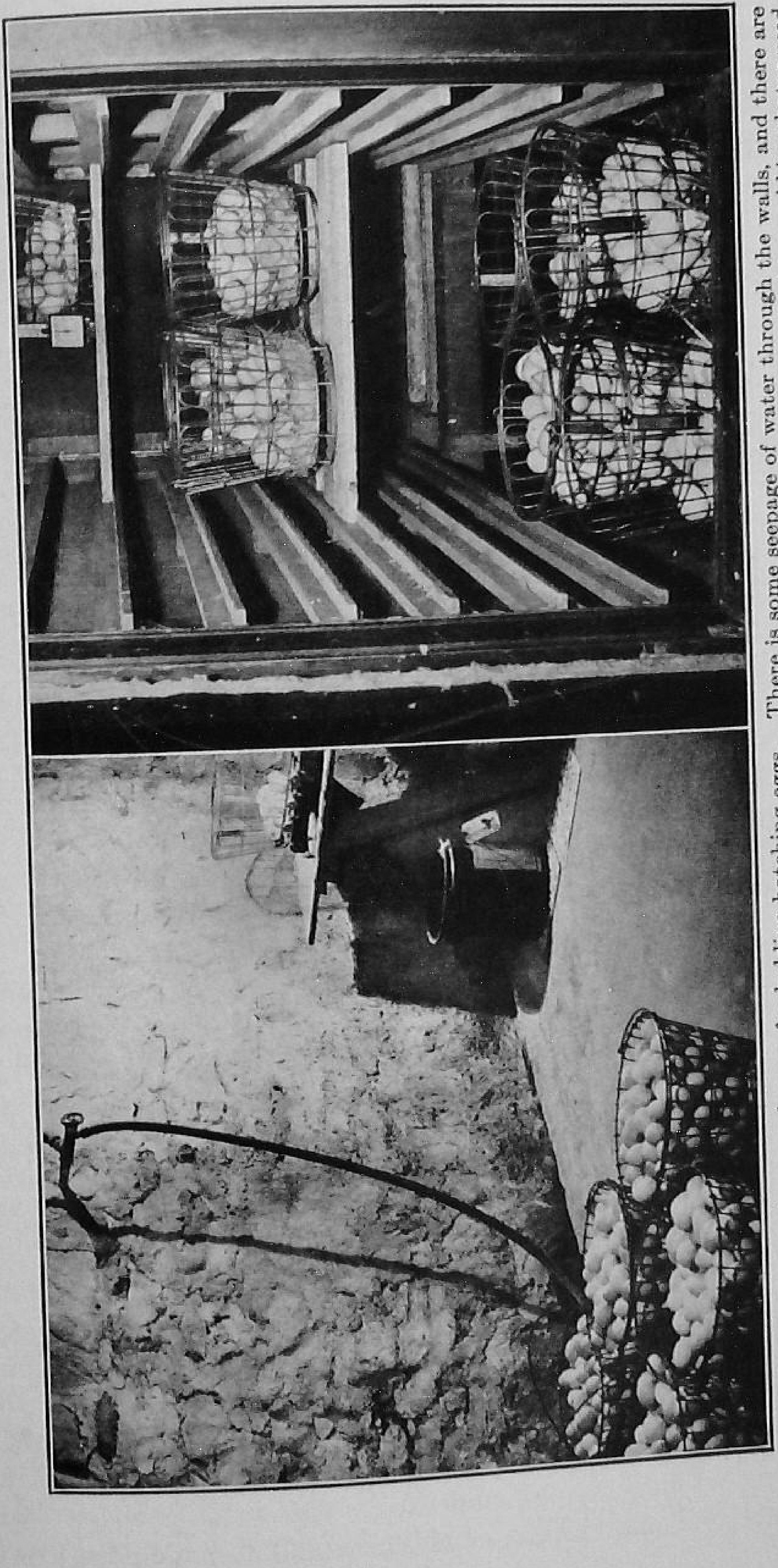

FIG. 89. Left, an underground room for holding hatching eggs. There is some seepage of water through the walls, and there are gutters on two sides of the room, permitting spraying the walls in dry weather to increase humidity. Right, an old incubator used for holding hatching eggs. The well-insulated walls and a circulating fan help to provide satisfactory humidity and storage conditions. (*S. M. Pearsall and I. Pearsall, Hall Brothers Hatchery, Inc.*)

Age of Eggs. Only fresh eggs should be set, because eggs for incubation deteriorate rather quickly after they are about 5 days old, while eggs 3 weeks old or more usually do not hatch at all.

Position during Storage. From the results of various investigations it is apparent that there are no advantages in keeping eggs in any particular position while being held for incubation, provided they are not kept over 5 days. They may be kept in a tray in their natural position and do not require turning.

Storage Temperature. The temperature at which eggs are held prior to being incubated is quite important, a high temperature being more injurious than a low temperature. Just how low the temperature may be allowed to go without endangering embryonic development has not been determined, although rather low temperatures up to about 10 hr. do not seem to be particularly detrimental.

As a general conclusion of various investigations on the proper temperature at which to hold hatching eggs, it is apparent that about 50°F. is the best temperature. In warm weather, eggs should be gathered frequently and placed immediately in a temperature of about 50°F. In sections of the country where subzero weather prevails in the early hatching season, the eggs should be gathered frequently to avoid their becoming frozen or excessively chilled.

Storage Humidity. A relative humidity of about 80 per cent in the holding room seems desirable if eggs are held as long as 2 weeks. Mold growth on the shells can be suppressed by spraying with a copper sulfate solution or by keeping the air circulated by the use of fans.

ARTIFICIAL INCUBATION

The earliest of modern incubators appeared in England in 1770 and in America in 1844. The chief difficulty encountered in these early incubators was with respect to maintaining a satisfactory temperature for successful incubation. It was not long, however, before mechanical devices for controlling the temperature were perfected to such an extent that the temperature throughout the 21 days of incubation could be controlled within a degree Fahrenheit variation from day to day.

Kinds of Incubators. There are several different makes of incubators which differ in design, size, kind of fuel used, method of heating the eggs, method of ventilating the egg chamber, and method of providing humidity, so that it is practically impossible to classify them in any systematic manner.

As far as design is concerned, incubators vary from the very simple boxlike or circular incubator of small size and sometimes cheap design to the mammoth roomlike incubator of substantial design equipped with

a relatively elaborate, well-constructed mechanism for providing optimum conditions of incubation.

The size of incubators differs from one holding approximately 50 to one holding several thousand eggs.

The fuel used may be coal, oil, petroleum, gas, or electricity, which is in reality a medium for the transference of heat rather than a fuel. In small incubators coal oil is frequently used to supply heat to the egg

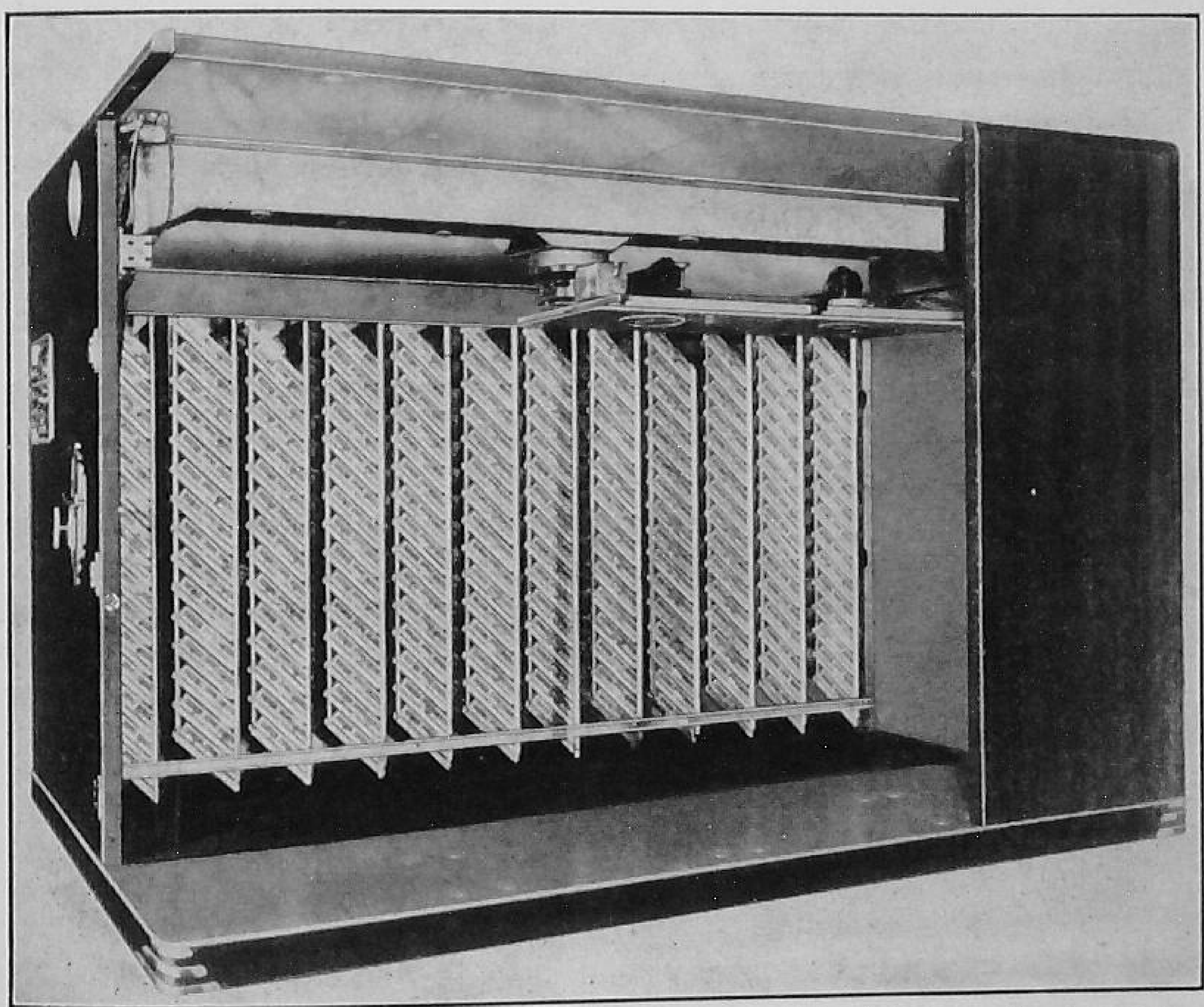

Fig. 90. Showing the inside of an automatically controlled incubator. (*Buckeye Incubator Co.*)

chamber. For incubators of larger egg capacity, gas, coal, or electricity is usually employed, the tendency being in favor of electricity. In sections of the country where natural gas is available, its use is usually justified from the standpoint of economy and ease of operation. Where neither gas nor electricity is available, coal may be used quite satisfactorily for supplying heat to large incubators in which hot water is used as a medium of heat transfer. The use of electricity in incubation is increasing in popularity because less labor is involved in incubator management, and when no heat is required, no electric current is used,

whereas when oil, gas, or coal are used, any surplus heat produced above incubation requirements is usually diverted from the egg chamber.

Hot water and hot air are the mediums employed in transferring heat from its source to the egg chamber, except in the case of electrically heated incubators, which have their electric resistance coils located in the egg chamber. The hot-water and hot-air methods of supplying heat are equally satisfactory except that the former is less responsive to outside changes than the latter. Within the egg chamber the eggs are heated by the radiation of heat from water pipes, by an air drum or electric coils, or by the conveyance of warm air directly to the eggs; or by diffusion; or in rare cases by contact.

The method of ventilating the egg chamber differs among the different makes of incubators, particularly with respect to those which are or are not provided with a mechanically forced circulation of air through the egg chamber.

The method of supplying humidity to the atmosphere of the egg chamber varies from water pans under the egg trays to a special automatic humidifying device.

Incubators differ with respect to the size of compartment for holding the eggs; there may be a large number of small compartments in what is frequently called the "section-type" incubator, or there may be one large compartment for holding all the eggs in what is known as the "cabinet-type," or "room-type," incubator.

The efficiency of operation of any particular make, design, or type of incubator depends largely upon the kind of materials used in its construction, how well it has been constructed, and its adaptability in providing the optimum conditions of incubation.

During recent years there has been a tendency on the part of the makers of large-capacity incubators to manufacture a separate hatcher to which eggs are transferred on about the eighteenth day of incubation. The use of the separate hatcher avoids any disturbance to eggs in the various stages of incubation prior to the eighteenth day. Moreover, there is no circulation or accumulation of down in the incubator used for incubating eggs up to the eighteenth day.

The Incubator Room. In order that the incubator may give the most satisfactory results in hatching chicks, it should be located in a separate room not used for other purposes in order that (1) the incubator and incubator room may be kept as clean and free from disease organisms as possible; (2) an even temperature may be maintained in the room, thus making it easier to regulate the temperature in the incubator; (3) good ventilation may be secured to provide the incubator with fresh air and to remove the excess carbon dioxide given off from the incubator; (4) to

make it a simple matter to provide the air of the incubator chamber with the proper relative humidity.

Section-type incubators require sufficient space between the incubator and the walls to permit the easy handling of the egg and chick trays and water trays, if they are used. Cabinet-type incubators are usually placed along the walls of the incubator room, with enough space left in the rear to make any necessary adjustments and to provide for proper cleaning.

A cellar room in the house may be used for small incubators, but for incubators of several thousand egg capacity a room entirely aboveground

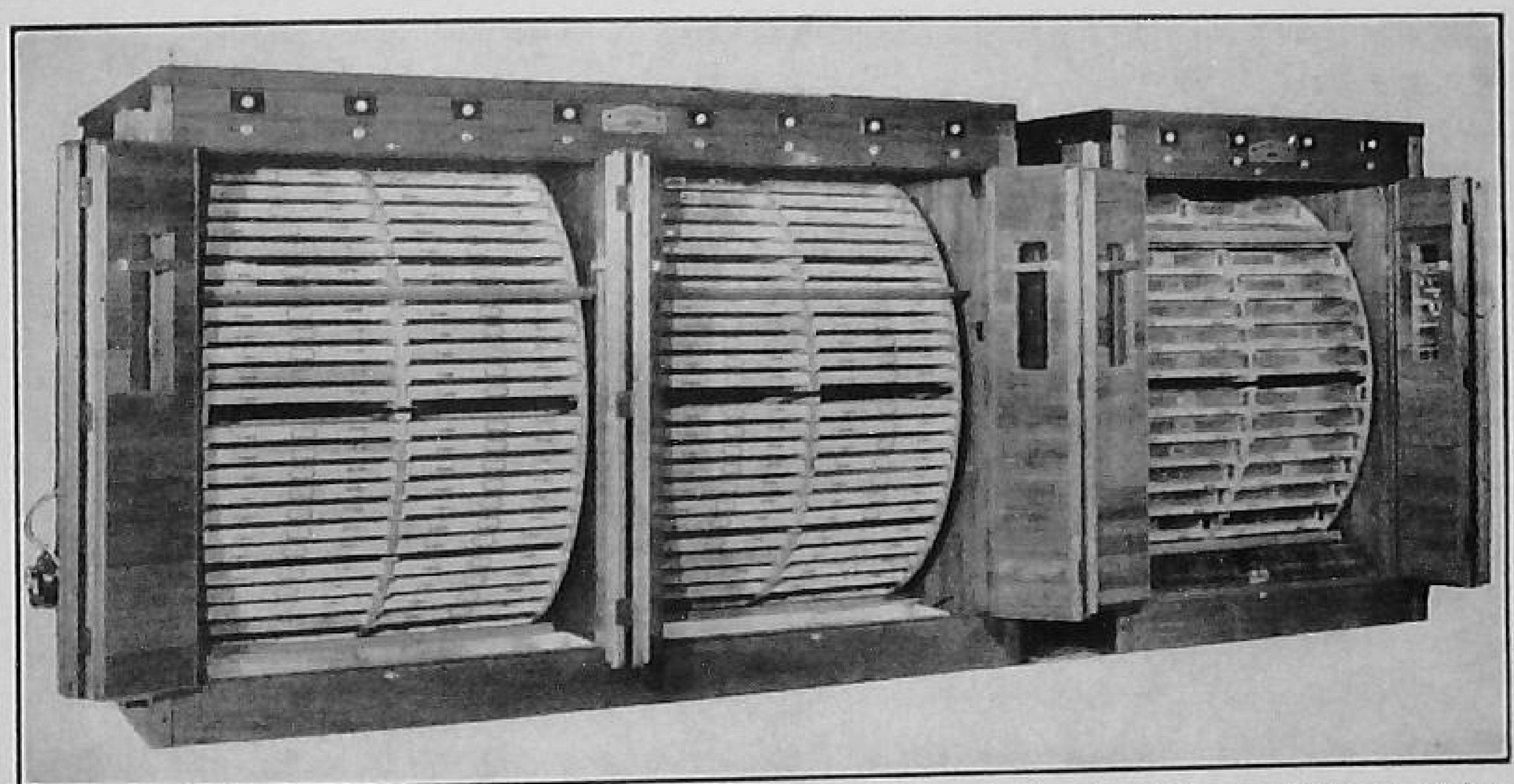

Fig. 91. Showing the incubating section at the left and the hatching section at right (*Petersime Incubator Company.*)

is usually used. Manufacturers of various makes of incubators furnish plans of satisfactory incubator rooms.

Testing Thermometers. Test all thermometers once a year with a clinical thermometer, which may be procured from a physician or at a drugstore. Place the thermometers, including the clinical thermometers, in warm water, heated to about 103°F., taking care to keep the bulbs near each other and at the same level in the water. Incubator thermometers, if correct, register the same temperature as the clinical thermometer.

Starting the Incubator. The printed regulations supplied by manufacturers should be followed closely until experience enables the operator to determine any minor variations that may be desirable. As pointed out previously, the forced-draft type of mammoth incubator requires a lower temperature than small incubators or mammoth incubators of the section type.

New incubators should be started about 1 week before they are to be

used in order that the proper temperature may be maintained and in order to make sure that the ventilating and humidifying apparatuses are functioning properly. The manufacturer's directions should be followed closely.

Care of the Heater. In the case of incubators heated with coal or gas, the heaters should be thoroughly cleaned at frequent intervals. The flues and pipes should be kept in such condition that the heat supply at all times will be regular.

In the case of electric incubators, the heating elements should be inspected and tested before the incubation season begins. The electric

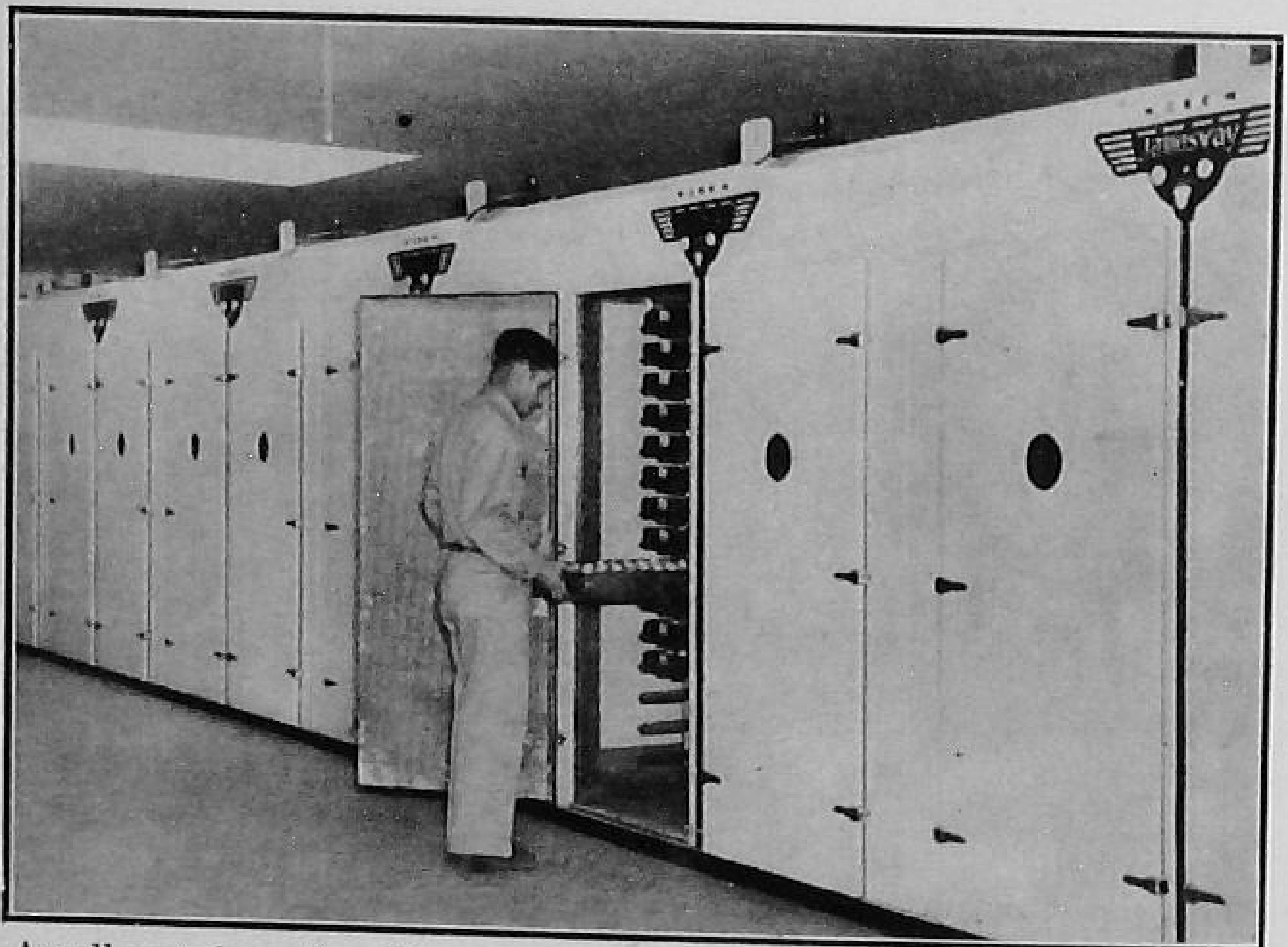

Fig. 92. An all-metal, sectional-type incubator, in use in Iowa. The section with the door open is used for hatching. (*James Manufacturing Co.*)

wires or coils should never be allowed to get wet, and the make-and-break switch should be kept free from oil, dirt, and dust.

Effects of Current Interruption. Although practically all modern makes of electric incubators are so well constructed that trouble is rarely experienced with respect to current interruption, occasionally a heating element may get out of order. Then, again, the thermostat may stick and cause overheating. The greatest danger with respect to current interruption is usually due to storms or floods which affect the central station or the home lighting plant. These interruptions are usually of short duration, largely because of the existing interconnection of power lines. Where such do not exist, it may be advisable for the hatchery operator to install an auxiliary current-producing plant.

The results of one test demonstrated that 12 hr. of current interruption

under room temperatures approximating 70° produced an average decrease in hatching results of 3.4 per cent. It would appear, therefore, that except under extraordinary circumstances of prolonged current interruption no serious results should follow.

Alarm Systems. All electric incubators should be equipped with an alarm system to warn the operator of an underheat or overheat supply. An alarm system that operates immediately when electric-current interruption occurs is vitally necessary in order that the attendant may close the ventilators of the incubator to conserve heat. A reliable alarm system to warn of an overheat supply is also necessary to provide against excessive embryo or hatching-chick mortality.

Testing Eggs during Incubation. The eggs should be tested twice during the period of incubation, from the fifth to the seventh days, to remove all infertile eggs and those with dead embryos; and from the fourteenth to the eighteenth day to remove embryos dying after the first test. Many operators of mammoth incubators make one test about the fourteenth day, removing all infertile eggs and dead embryos at that time. Some operators do no testing during the entire period of incubation.

The testing should be done in a dark room or with a special device that can be used in the daytime. The eggs are tested with the large end up, so that the size of the air cell as well as the condition of the embryo may be observed readily. The infertile egg when held before the testing or candling device looks clear. A fertile egg tested at about the seventh day of incubation shows a small, dark spot, with a mass of little blood vessels extending in all directions if the embryo is living. If the embryo is dead, the blood settles away from the embryo toward the edges of the yolk, forming in some cases an irregular circle of blood known as a "blood ring."

At the second test, on the fourteenth day, the eggs containing strong, living embryos are dark and well filled and show a distinct line of demarcation between the air cell and the growing embryo, whereas eggs with dead germs show only partial development and lack this clear, distinct outline.

In actual practice, hatchery operators, for the most part, candle eggs on the eighteenth day when those with living embryos are transferred to the hatching trays. This means a saving in time and labor in testing and decreases the amount of space needed in the hatching trays.

Fertile and infertile eggs can be identified with a high degree of accuracy after about 15 hr. of incubation. For this purpose a 75-watt blue-green bulb should be used, or the person doing the candling should wear blue eyeglasses. The fertile egg can be detected by the presence on the surface of the yolk of a small spot about the size of a dime. The spot

represents the embryo which causes the yolk surface to bulge slightly. Infertile eggs show no signs of embryo development.

Taking Off the Hatch. The incubator doors should not be opened after the eighteenth day until the hatch is practically completed, for the simple reason that opening the doors lowers the temperature and decreases humidity. In the case of cabinet-type incubators, the first chicks to hatch are often removed before the hatch is completed, especially if the hatching trays are crowded as the result of a very successful hatch. Empty shells are removed at the same time, but care must be taken not to chill the chicks still hatching.

Disposal of Infertile Eggs and Unhatched Chicks. Incubation wastage in the form of infertile eggs and unhatched chicks could either be burned or boiled thoroughly and used as hog feed.

Disinfecting Incubators. After an incubator has been used once, it should be thoroughly cleaned and disinfected, especially to prevent the spread of pullorum disease. Aside from the possible spread of pullorum disease, however, it is perfectly obvious that filth tends to accumulate in incubators that are used time after time and that the greatest possible precautions should be taken to clean and disinfect them thoroughly after each hatch, because most diseases are filth-borne. The egg trays and the inside of the incubator should be cleaned out thoroughly after each hatch and thoroughly disinfected with a 3 per cent solution of any of the standard coal-tar stock dips. The proper precautions to take to prevent the spread of pullorum disease in incubators is discussed fully in the chapter on Disease Prevention.

Insurance Restrictions When Using Incubators. Farmers and others using incubators should keep in mind that there are certain restrictions on fire insurance of dwellings and other buildings in which incubators are used. Some insurance policies have no restrictions, whereas others have definite specifications to which the use of incubators must conform, and still others prohibit the use of incubators in any manner. In some cases special permission is required to operate an incubator. In any case it is well to look into the matter of insurance restrictions with respect to the use of incubators in dwellings and other buildings.

HATCHERY-MANAGEMENT PROBLEMS

In 1918 it became possible to ship baby chicks by parcel post, resulting in a phenomenal growth of the hatchery industry.

Successful Hatchery Operation. In order to operate a hatchery most successfully, certain principles of fundamental importance must be kept in mind. The various items that determine the results from the operation of a hatchery would include:

1. The knowledge the hatchery operator possesses concerning poultry and the poultry industry. The greater the poultry knowledge the hatchery operator possesses, the more likely is he to command respect and confidence among farmers and poultrymen who buy chicks.

2. A pleasing personality is an important factor in enabling the hatchery operator to command the respect of the flock owners supplying eggs to his hatchery.

3. Good business ability is most essential in successful hatchery operation not only from the standpoint of keeping accurate records of expenses and receipts in the operation of the hatchery but also from the standpoint of selling his chicks to best advantage. To ignore the vital necessity of keeping complete records in the operation of a hatchery is to invite failure. In order to manage a hatchery most efficiently, the hatchery operator must practice sound business methods.

4. The location of the hatchery is an important factor in determining success, for the simple reason that most of the chicks are sold locally. Therefore, the hatchery should be located where there is likely to be a good demand for chicks within a radius of approximately 50 miles from the hatchery. Plenty of parking space around the hatchery plant is desirable.

5. The hatchery plant should be attractive in appearance, both outside and inside, should be kept clean and sanitary, and should be so arranged as to promote the greatest efficiency in its operation. Prospective purchasers of chicks often pass judgment on the chicks produced by the appearance of the hatchery plant. The layout of the hatchery plant should provide for the convenience of flock owners delivering their eggs and for chick customers.

The office should be in a separate room, and if possible the machines in which the chicks are hatched should be kept in a separate room from that containing the incubators in which the eggs are incubated up to the eighteenth day. A large hatchery plant should provide an egg-receiving-and-traying room where the eggs are received from the flock owners, sorted, and trayed. This room should be kept at about 50°F., and the air should have a relative humidity of about 60 per cent. The general supply room in which egg cases and chick boxes are kept should also be separate from the incubating and hatching rooms. There should be a chick-sorting-and-shipping room.

Cement floors with drains are most desirable for the incubator rooms because they can be kept clean and sanitary and also because they can be watered for the purpose of maintaining the proper degree of relative humidity. The incubators should be placed on bases so that the bottom of the incubator is 2 or 3 in. above the floor.

The proper ventilation of the incubating and hatching rooms is imperative in order to provide the embryos and chicks with a sufficient supply of oxygen and to remove the carbon dioxide liberated by the embryos and chicks. The cooperation of the incubator manufacturer should be sought with respect to providing adequate ventilation for the incubators installed.

The temperature of the incubating and hatching rooms should be kept as near 70°F. as possible.

The Egg Supply. Since the majority of hatchery operators do not possess flocks of sufficient size to produce all the eggs for the hatchery, it is necessary for them to purchase eggs from a number of flock owners. Therefore, it is obvious that if the hatchery operator is to secure the best results in hatching he must take a vital interest in the quality of eggs produced by the flocks from which he secures hatching eggs.

One of the most important things for the hatchery operator to keep in mind at all times is that the quality of hatching eggs cannot be improved after they are produced. The hatchability of the eggs determines the number of chicks to be secured, assuming that conditions of incubation and the management of the hatchery are ideal. Good chicks cannot be hatched from poor eggs. Furthermore, poor-quality chicks usually require more replacements and give rise to more dissatisfied customers; repeat orders decrease, and the hatcheryman's reputation is impaired. Therefore, the hatchery operator is under distinct obligation to all flock owners supplying eggs to his hatchery to cooperate with them in a sound breeding and improvement program designed to supply the hatchery with the highest possible quality of hatching eggs. This is in the best interests of the hatchery operator as well as in the best interests of the flock owners.

One of the very best incentives to encourage flock owners to produce eggs of the highest possible hatchability is for the hatchery operator to pay a premium for the hatching eggs he receives from each flock owner on the basis of the hatching results secured from week to week, the premium on the basis of hatchability being in addition to the ordinary premium over the price of market eggs.

For the average hatchery, approximately 1,000 to 1,200 breeding females are needed for each 10,000-egg capacity. The number of flocks required depends, of course, upon their size, but it should be obvious to any hatchery operator that a flock owner having 300 or 400 birds can be more readily induced to undertake a sound breeding and flock management program for the production of high-quality hatching eggs than a flock owner having only 50 or 100 birds.

Hatchery operators should enter into agreements with flock owners

supplying eggs to their hatcheries whereby the flock owner agrees to furnish hatching eggs of a certain minimum size, keep and feed his flocks according to the directions supplied by the hatchery operator, and have the flock officially tested for pullorum disease. The most successful hatchery operators are those who secure the most complete cooperation of their flock owners based on the mutual benefits accruing to all.

Length of Hatching Season. Except in those localities where there is an extensive commercial-broiler industry, most hatcheries sell the great majority of their chicks between the first of March and the last of May, the peak of the output being during April. The hatching of chicks during January and February has increased during recent years because the pullets raised can be used to replace birds culled from the laying flock.

Avoiding a Surplus. One of the cardinal principles in the successful operation of a hatchery is to avoid the accumulation of surplus chicks beyond the number ordered for sale. Hatchery operators should avoid surpluses by setting eggs according to the number of chicks ordered. The most successful operators, who have established a reputation for the quality of chicks they sell, usually have no difficulty in disposing of the same or an increasing number of chicks year after year. It is to the hatchery operator's own advantage to set only a sufficient number of eggs to fulfill the chick orders on hand, except for a reasonable allowance for late orders.

Sexing Chicks. The business of segregating males and females among day-old chicks by examining the rudimentary copulatory organs has become well established in some sections of the country. The sexing of chicks at hatcheries is carried on most extensively in the commercial Leghorn sections of the Pacific Coast states, where there is usually a limited market for Leghorn cockerels as broilers.

Success in sexing chicks depends upon one's ability to distinguish the rudimentary copulatory organ or process, which is nearly always present in a well-developed condition in males but is nearly always absent in females. A considerable amount of training and experience is necessary to enable one to sex chicks with a high degree of accuracy at a fast enough rate to make the undertaking an economic success at most hatcheries.

Since several different kinds of processes are encountered and the technique of sexing is rather complicated, lack of space prevents a detailed discussion of the various processes and means of identifying them. The proper training in sexing chicks can best be obtained from a thoroughly experienced operator.

Selling and Shipping Chicks. Selling the chicks produced at a hatchery plant to best advantage is of paramount importance in the successful operation of a hatchery. The chicks should be priced, of course, in rela-

tion to their quality. The selling of chicks below the cost of production is distinctly detrimental to the best interests of the hatchery business and the poultry industry and ought to be discontinued. Moreover, the shipping of chicks to chick auctions and shipping to fictitious addresses are practices that should be prohibited for the simple reason that they interfere unfairly with the legitimate operations of honorable hatchery operators.

In the advertising and selling of chicks, the fair-trade practice rules for the baby-chick industry of the Federal Trade Commission should be followed implicitly.

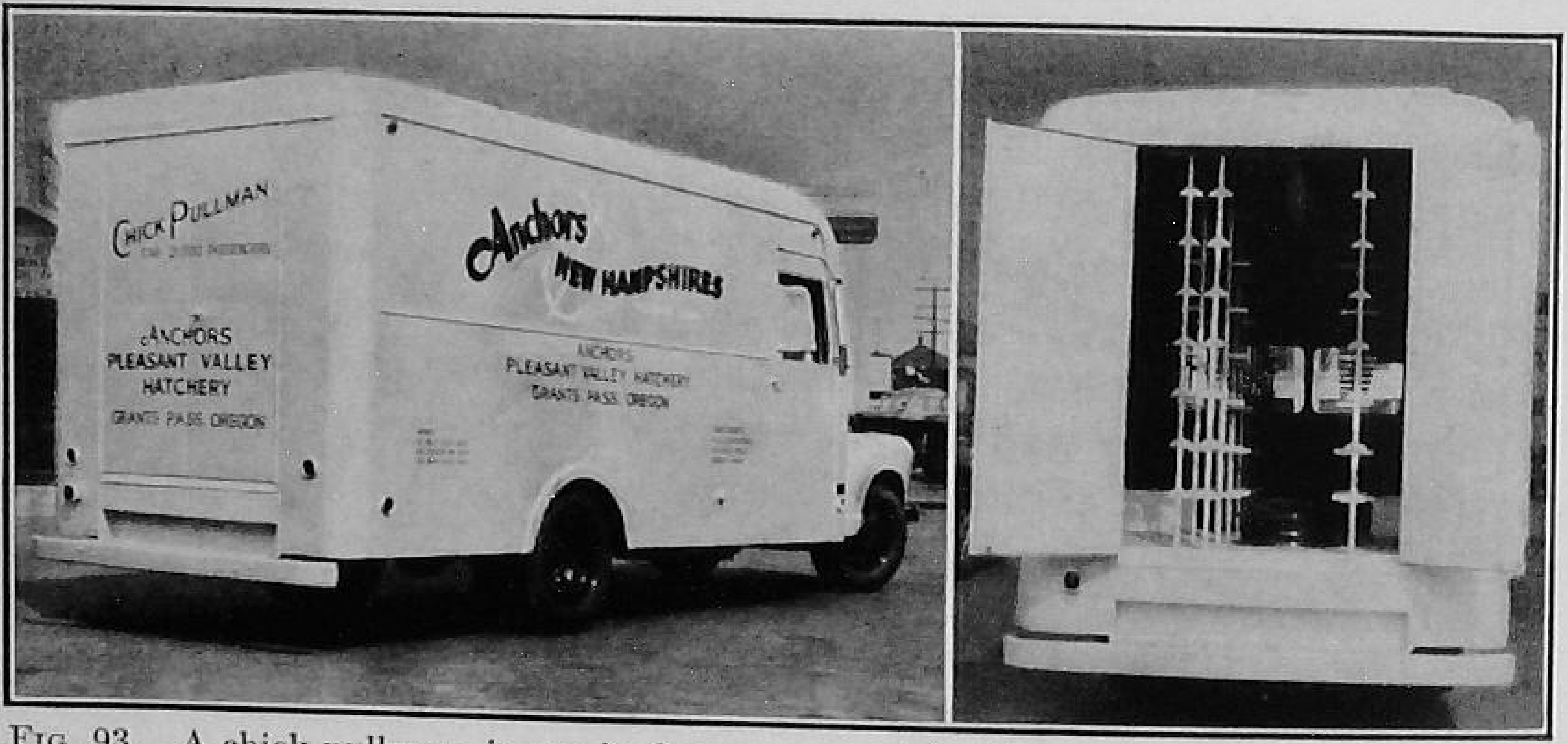

Fig. 93. A chick pullman, in use in Oregon, provided with stanchions which permit free circulation of cooled or heated air around each chick box. The stanchions are removable to permit return trip with a truckload of hatching eggs. (*V. E. Hansen, Wentworth and Erwin Company.*)

The successful selling of baby chicks depends, first, upon the quality of chicks being offered for sale and, second, upon the ingenuity of the hatchery operator. The hatchery operator who has established a reputation for selling high-quality chicks that live and do well in the hands of the customer usually has no difficulty in maintaining an established business.

The newly hatched chicks should be culled carefully, preparing for shipment those with bright eyes, bright-yellow beaks and shanks in yellow-skin breeds, and pinkish-tinged beaks and shanks in white-skin breeds, well fluffed-out down, freedom from defects and deformities, and well healed at the vent. The shipping of high-quality chicks to customers is a good investment.

Chicks are usually shipped in boxes containing 100 chicks, the box being divided into four compartments each containing 25 chicks.

The chick boxes should be properly ventilated according to the season of the year.

The number of boxes that can be tied together for parcel-post or express shipment is governed by regulations of the U.S. Post Office Department, and these should be followed in order to secure the most

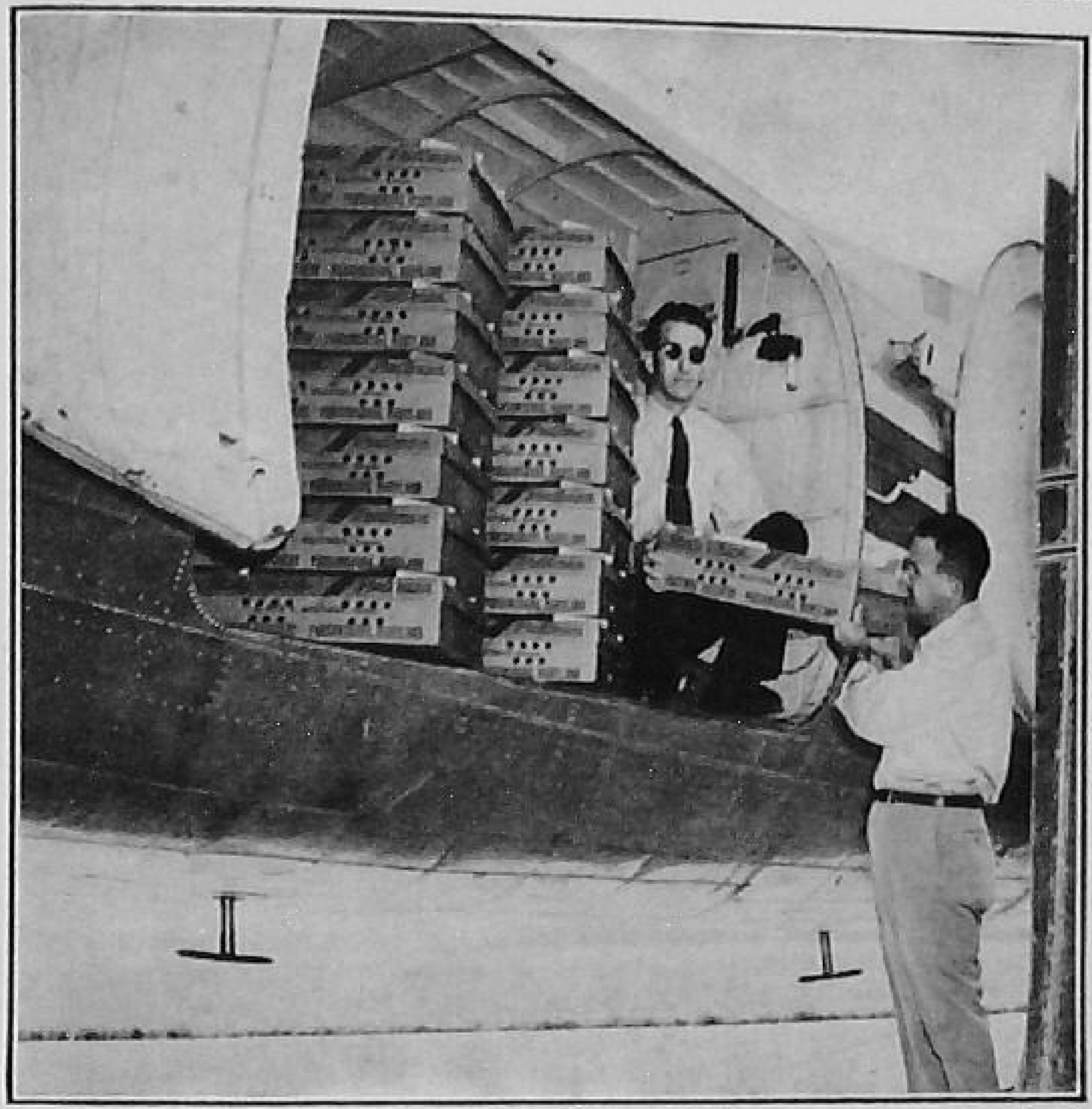

FIG. 94. Millions of baby chicks are shipped by airplane every year, including many to foreign countries. (*H. F. Williamson, Hastings Hatchery.*)

satisfactory service in the shipping of chicks by parcel post. Whether chicks are shipped by parcel post, express, or airplane, they are expected to reach their destination within 72 hr. from the time of hatching.

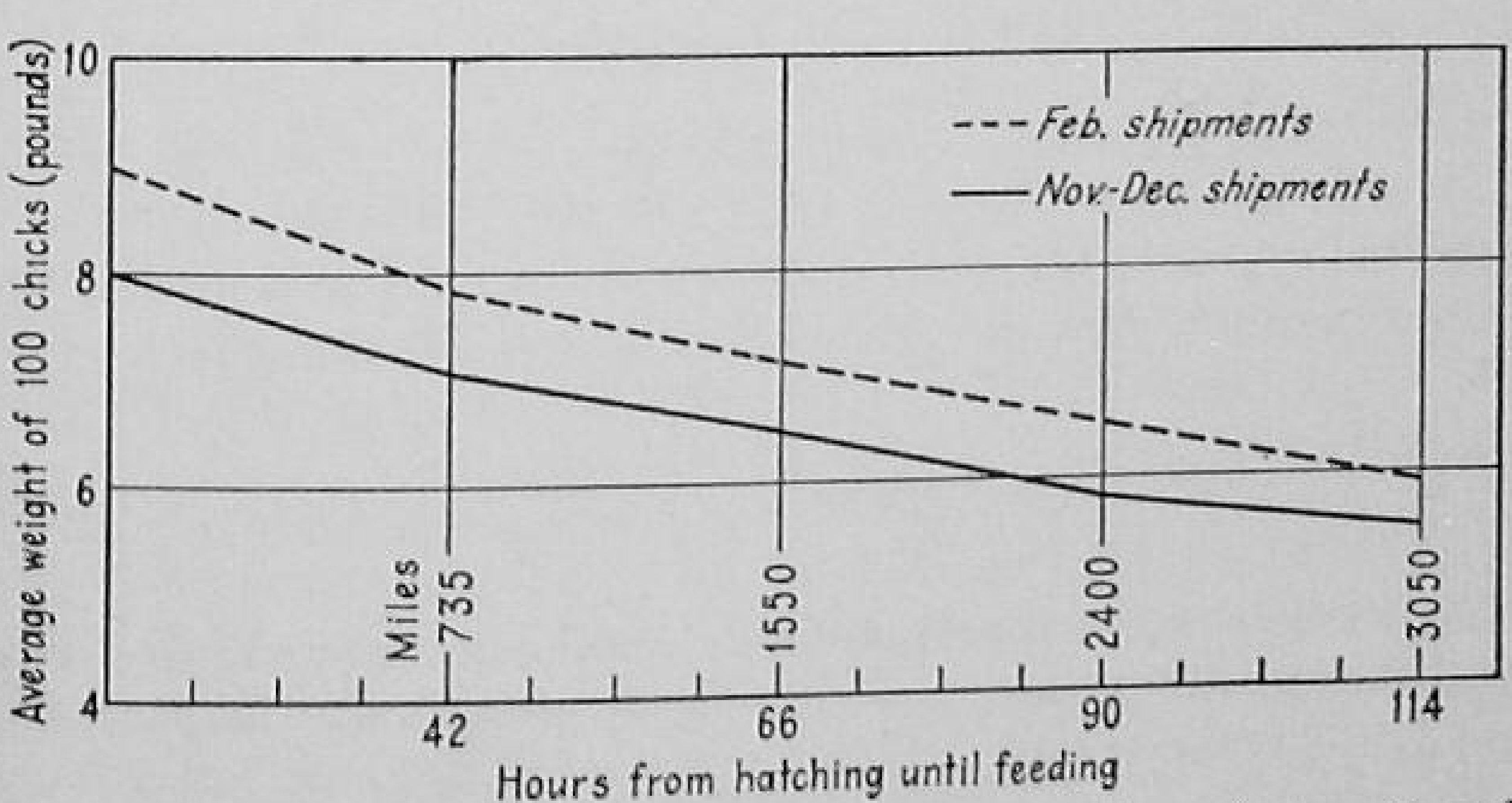

FIG. 95. Showing loss in weight per 100 chicks according to hours in transit and distance shipped by express. (*M. W. Olsen and B. Winton.*)

Special-delivery trucks, sometimes equipped with a special ventilating device, are used by many hatchery operators in delivering their chicks to customers.

The greater the distance that chicks are shipped and the longer the time between the time the chicks are hatched and the time they are fed after being delivered, the greater is the loss in weight, as shown in Fig. 95. In order to avoid excessive loss in weight and excessive mortality both during transit and after the chicks have been placed under the brooder stoves, not much over 60 hr. should elapse between hatching time and feeding time.

The Responsibility of the Hatchery Operator. The evolution of the hatchery industry has demonstrated that the hatchery operator is coming to assume a more dominant role than ever in the future development of the industry simply because each succeeding year sees a relatively higher proportion of the country's chick population secured from the breeder and commercial hatcheryman. To a considerable extent the hatchery operator is responsible for improving conditions in the poultry industry because the quality of chicks produced by hatcherymen determines, in a large measure, the results that farmers and commercial poultrymen secure from the chicks they purchase. It is obvious, therefore, that the character of business done by the hatchery operator has a very direct bearing on the future development of the poultry industry.

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CHAPTER 7

REARING PRINCIPLES AND PRACTICE

The rearing of chickens is a matter of interest to practically every farmer and commercial-poultry producer, all of whom anticipate rapid growth and low mortality in the chicks they start each year. The quality of chicks purchased has an important bearing on results secured in brooding.

In addition to the effects of heritable chick quality on rate of growth and mortality, other factors are also of importance. The kind of diet fed, the method of feeding, and the environmental factors of brooding all influence results secured. Since rate of growth is so intimately related to feed consumption, comments on these problems are naturally reserved for the appropriate chapter later.

One other factor of tremendous importance in determining results in brooding and rearing chickens is the ability and willingness of the operator to give proper attention to numerous details of management. Lack of interest in keeping parasites and disease organisms under control and carelessness in management practices are common causes of failure in raising chickens.

THE CHICK SUPPLY

Probably over 90 per cent of all chickens raised in the United States every year are secured from hatcheries. It is for this reason that purchasers of chicks should give most serious consideration to the kind of chicks purchased.

Chick Quality. Since so many of the chickens raised each year are secured as chicks from hatcheries, it is quite apparent that the hatcheries occupy a very important place in the poultry industry. When intending to purchase day-old chicks from a hatchery, a person should take into consideration several factors in the operation of different hatcheries before deciding from which to purchase. There are certain advantages in purchasing from a local hatchery in the community, provided that chicks of the desired quality can be secured. The best kind of chickens to obtain are those produced by hatcheries that carry on some kind of poultry-improvement work, including the breeding of selected stock noted for rapid growth, early feathering, good fleshing, and high egg

production. Results secured in meat and egg production depend to a large extent on the quality of chicks secured.

Persons intending to purchase chicks should realize that good chicks cannot be hatched from poor eggs. If the hatchery operator is not carrying on a sound selection and breeding program, his chicks could not be expected to give the most satisfactory results.

Many hatchery operators who secure their hatching eggs from hatchery flocks give the flock owners instruction in culling and inspect the flocks

FIG. 96. Left, a hatchery-flock owner is given instruction in selecting breeding stock with the idea of improving chick quality. Right, recording egg production and egg weight is one of the first steps in developing a progeny-testing breeding program to improve the laying ability of a strain. (*University of Maryland.*)

at intervals. Hatching eggs are selected carefully and should weigh at least $1\frac{1}{12}$ oz. each (22 oz. per doz. from June 1 to Dec. 1 is permissible for eggs hatched as "broiler chicks").

Chicks from Flocks Tested for Pullorum Disease. The organism which causes pullorum disease often becomes localized in the ovary of the female breeder and may be present in the egg when it is laid. Thus pullorum disease may be transmitted from the dam to her chicks through the egg. When infected eggs are incubated, some of the chicks hatched may be infected. Chicks that are infected with the pullorum organism usually suffer heavy mortality, especially during the first 3 weeks. It is for this reason that breeding flocks should be tested at least once every

year in order to determine the presence of any birds that harbor the organism.

Reactors should be removed upon completion of the test, and the premises must be thoroughly cleaned and disinfected immediately. Incubators should be disinfected by fumigation to prevent possible spread of the disease at hatching time. A flock containing one or more reactors should be retested.

The importance of securing chicks from hatcheries carrying on a pullorum-testing program under official state supervision cannot be

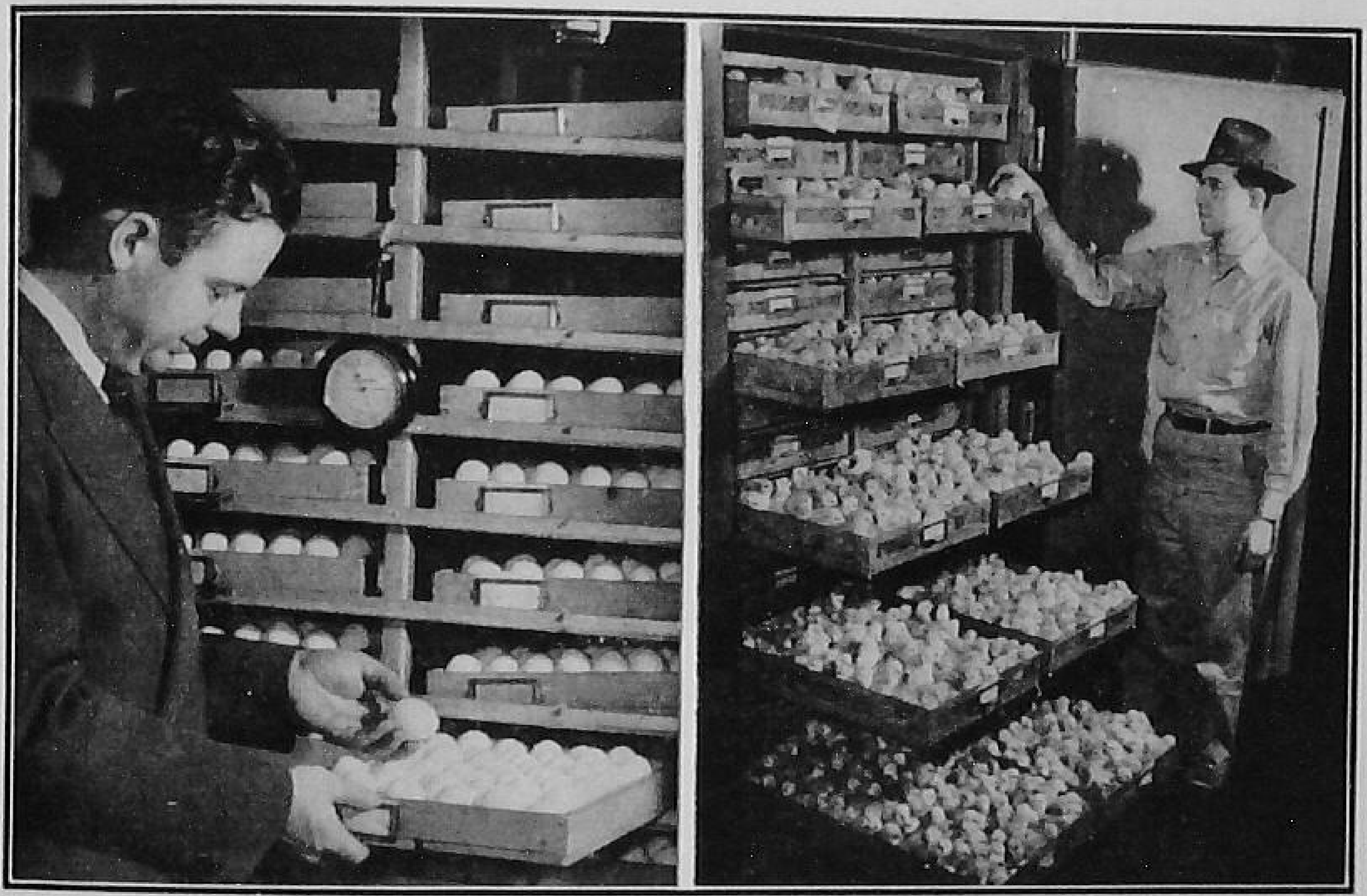

FIG. 97. Left, the eggs secured from a hatchery-flock owner are examined at traying time. (*University of Maryland.*) Right, a very successful hatch is obtained from eggs produced by a carefully selected breeding flock. (*Buckeye Incubator Company.*)

emphasized too strongly. Chicks infected with the organism that causes pullorum disease may suffer as much as 50 or 60 per cent mortality.

"Straight-run" or "Sexed" Chicks. The term "Straight-run chicks" refers to chicks of both sexes in the proportion in which they normally occur, which is in about equal numbers of both sexes. The term "Sexed chicks" refers to chicks that have been separated according to sex at hatching time, it being possible to purchase either cockerel chicks or pullet chicks. When purchasing straight-run chicks, purchase about three chicks for every pullet that is to be placed in the laying house. About one-half of the chicks will be cockerels, and due allowance must be made for growing-chick mortality and for culling unsuitable pullets at housing time.

Pullet chicks usually cost slightly more than twice as much as straight-run chicks, whereas cockerel chicks are usually sold at a relatively low price. One advantage in purchasing pullet chicks is that pullets raised without cockerels are likely to develop more uniformly than those raised with cockerels. Cockerel chicks are usually purchased for broiler or roaster production. Some commercial-broiler producers purchase both sexes of sexed chicks and raise the sexes separately in order to secure more uniform growth.

"Started" Chicks. "Started" chicks are those which have been fed and watered and brooded by the hatchery operator, usually from 2 to 4 weeks, before being shipped to the customer. The demand for started chicks resulted from the desire of purchasers to avoid the first few weeks' period of brooding, during which time the major part of chick mortality usually occurs. Started chicks naturally cost considerably more than day-old chicks, the price charged depending largely upon the age at time of shipment.

Many hatchery operators brood their started chicks in battery brooders. Therefore, when a customer purchases started chicks, great care must be taken to make sure that the chickens become adapted to brooding on the floor, if that method of raising is employed by the purchaser. Watch the chickens carefully for two or three nights at bedtime to make sure they are properly distributed under the hover.

Securing Plenty of Chicks. Enough chicks should be purchased to provide for rigid culling and still have enough left for the purpose intended. Some allowance must be made for mortality. Most flock owners do not cull their growing stock nearly so much as it should be culled, with the result that a lot of poor-quality pullets are often placed in the laying house. Securing plenty of chicks to allow for rigid culling is very important, but at the same time overcrowding the brooders and brooder houses is to be avoided.

Time to Secure Chicks. The proper time to buy chicks depends, of course, upon the purpose for which the chicks are being bought. Chicks for broiler production are bought every month in the year. Most chicks bought by farmers and commercial poultrymen are obtained for the purpose of raising pullets as replacements in the laying flock. In order to have the pullets begin laying in September, Leghorn chicks should be purchased from about Mar. 15 to May 1, and chicks of the larger breeds should be purchased from about Mar. 1 to Apr. 15. Earlier hatched chicks are sometimes purchased by commercial market-egg producers in January and February, as pointed out in the previous chapter.

In southern parts of the country April- and May-hatched chicks do not grow so well during the first few weeks as February- and March-

hatched chicks. The high temperatures that usually prevail in the southern sections of the United States during the summer months tend to retard growth.

For the purpose of securing egg production from pullets when the yearling and older hens are molting, during June, July, and August, some poultrymen purchase chicks in November and December. Fall or winter chicks require more careful management than chicks bought during the spring months.

The data in Table 30 show the advantage of buying chicks before April as compared with buying chicks later.

TABLE 30. LABOR RETURNS FROM LAYERS PURCHASED AS CHICKS BEFORE APRIL, DURING APRIL, AND AFTER MAY 1, RESPECTIVELY, CENTRAL INDIANA, 1945 TO 1946
(H. A. Johnson, L. S. Robertson, and J. W. Sicer, 1948)

Item	Chicks purchased		
	Before April	During April	After May 1
Average No. of layers	159	155	131
Labor returns per 100 layers	$94	$74	$-8

TYPES OF BROODERS

There are several different types of brooders, which vary according to size, design, and kind of fuel used to provide heat.

Lamp brooders, using kerosene as a source of heat, are satisfactory for small operators who raise about 50 chickens. These brooders may be made at home or purchased from a manufacturer.

Homemade brick brooders are used in some sections of the country. They use relatively green wood as a source of heat.

Most makes of brooders are portable and are equipped with hovers or canopies for conserving heat to a limited area near its source. The kind of fuel used to supply heat in colony brooders may be kerosene, coal, wood, distillate oil, gas, or electricity.

Continuous brooders used by large operators are heated by burning coal, gas, or distillate oil. Hot water or warm air is distributed from a central-heating system. In some cases steam is piped to heat exchangers.

Battery brooders are usually heated electrically, although some of them are heated by burning coal, gas, or distillate oil.

The choice of a brooder for a particular poultry raiser is governed by (1) the number of chickens to be brooded each year; (2) the initial cost

and relative durability; (3) efficiency of operation; (4) the dependability of different fuel materials; (5) the personal preference of the poultry raiser.

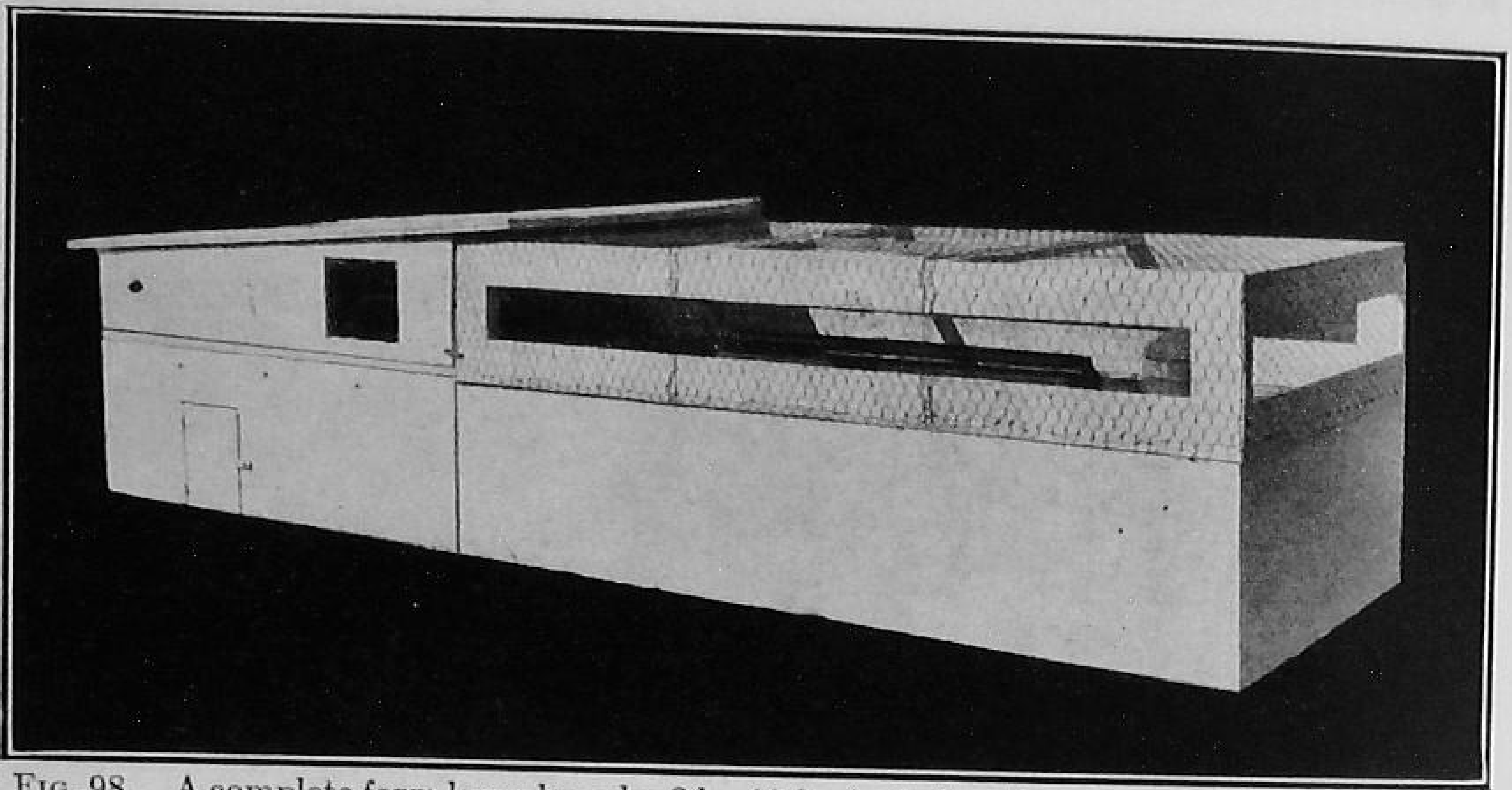

FIG. 98. A complete farm lamp brooder 3 by 10 ft., including brooding and sun-porch units. The door for tending the kerosene lamp is shown at lower left. (*N. R. Mehrhof and A. W. O'Steen, Fla. Agr. Ext. Service.*)

DESIRABLE BROODING CONDITIONS

Among the more important brooding factors affecting results secured in rearing chickens are: (1) temperature; (2) ventilation without drafts; (3) dryness and sunlight; (4) sanitation; (5) amount of floor space; (6) low fire hazard. All these factors are especially important during the brooding season, and some of them are very important after the growing chickens no longer need heat.

Temperature. For about the first 2 weeks of the brooding period, the temperature should be about 95°F. at about 2 in. above the floor at the outer edge of the house. Thereafter the temperature should be lowered about 5° each week, depending upon the time of year and the outside temperature. Some poultrymen who brood chickens with coal, wood, or oil-burning brooders start with a temperature of about 90°F. and gradually lower it each week. These temperatures apply to the area under the hover or canopy of the brooder.

In cold weather a temperature of about 70°F. should be maintained for the brooder house itself or the compartment not containing the heating elements in battery brooders. Chickens will do better in a fairly cool room or compartment, provided the right temperature is maintained under the brooder so that the chickens can go there to get warm when necessary.

Maintaining a uniform temperature under the hover or canopy during each weekly period is vitally important. This means that the brooder must be level. Excessive heat causes the chicks to pant, and if the brooder house is also too warm, the chickens are liable to crowd into the corners of the brooder house. On the other hand, too low a temperature will cause the chickens to huddle together under the hover or in a corner of the house, and some may become smothered. Sudden changes in temperature, either too high or too low, are objectionable. Chicks can

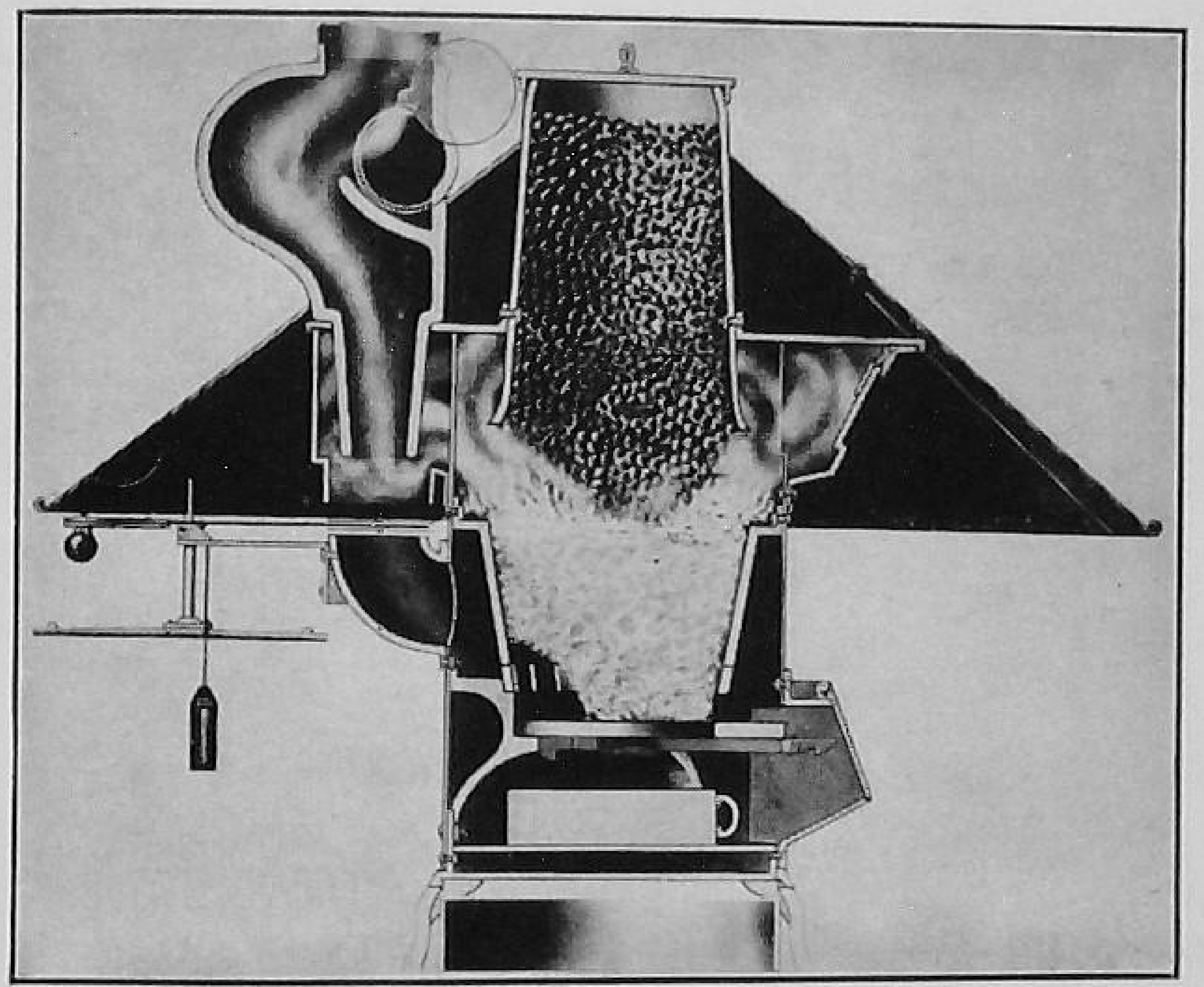

FIG. 99. The coal-burning brooder stove is one of the most successful ways of brooding chicks in colony-brooder houses. (*Buckeye Incubator Company.*)

stand being chilled for as long as 1.5 hr. at 37°F. without interfering with their rate of growth.

Maintaining the proper temperature on windy nights is frequently a problem when coal-burning and wood-burning brooders are used. If the fire goes out during the night because of too much draft, the chickens are certain to become chilled and are likely to pile up in a corner of the brooder house. A well-constructed, automatic wind damper set in the stovepipe decreases the tendency of the fire to go out, because the wind damper opens with the increasing draft that is caused by a strong wind.

The most critical period in brooding is the first 2 weeks; thus the most careful attention should be given to the brooder during this time. It is most important to see that the chicks spend the first night or two under the hover or canopy. This teaches them to go under the hover later, when they require warmth. Those who have had several years'

experience in brooding chickens, rather than relying on thermometers, are governed by the action of the chickens in regulating the thermostat to maintain proper temperature. When the correct temperature is maintained, the chicks spread out evenly under the hover or lay in a circle under the inside edge of the hover or canopy.

When the chicks are well feathered, they require little heat. Chickens brooded during the winter months may need a little heat up to about the eighth week. During the spring season, especially if the weather is warm, heat may be dispensed with after about 5 weeks.

Ventilation without Drafts. Proper ventilation of the brooder is necessary, since water vapor and carbon dioxide given off by the chickens

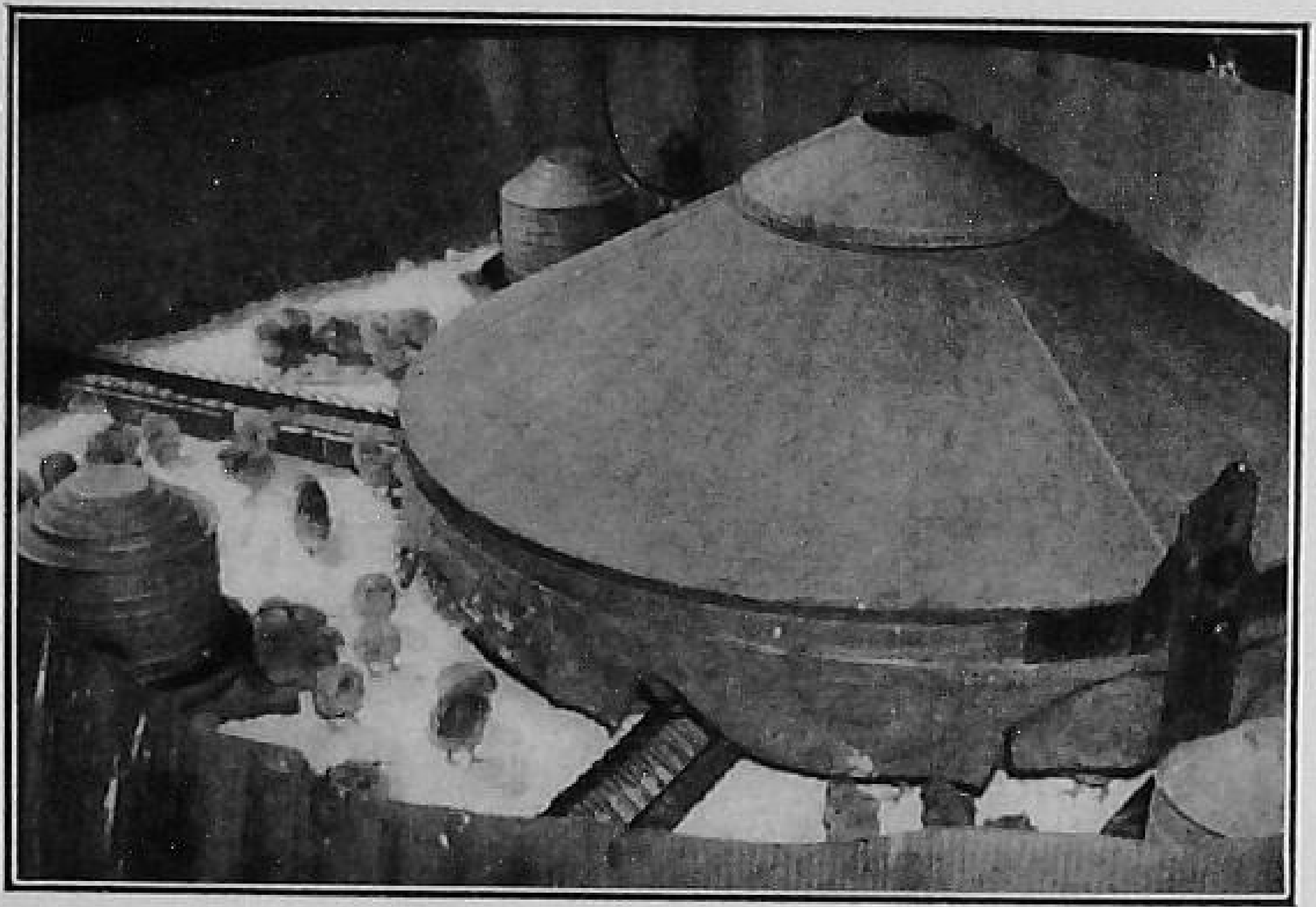

FIG. 100. An electric brooder surrounded by a cardboard guide for the first few days of brooding and with well-arranged feeders and waterers. (*University of Maryland.*)

tend to accumulate beneath the hover or canopy of the brooder, or when ventilation is restricted. At the same time, it is also very necessary to avoid drafts under the brooder and in the brooder house or compartment. Drafts should not be allowed to sweep across the floor of the brooder house, especially during the first 4 weeks of the brooding period.

Coal-burning and wood-burning brooders usually provide for good circulation of air, inasmuch as the hover acts as a deflector. Unless the hover has a positive system of fresh-air ventilation, however, it should not sit closer than about 4 in. above the floor; and if curtains are used, they should hang about 2 in. above the floor and should be raised as the chickens increase in size. Oil-heated, portable hovers also provide good ventilation because the heater radiates heat from the drum and the heated air which is poured under the hover displaces the cold air.

With the radiant-heat type of electric brooder, particular attention must be given to the problem of ventilation under the hover. The adjustable flue may be closed or opened to control the circulation of air.

In sections of the country where it is not too cold during the brooding season, the radiant-heat type of electric brooder may be placed on a frame covered with ½-in.-mesh hardware cloth, the top of the frame being about 2 in. from the floor. With the fan-ventilated type of electric brooder, ventilation is provided by an electric fan which forces air into the hover from above. With both types of electric brooders when used in northern sections, where the floor of the brooder house is apt to be quite cold early in the brooding season, it is well to put under the brooder a 1-in. pad of insulation board, or its equivalent, a little larger than the canopy of the brooder. When damp litter has to be removed, the fresh litter should be preheated before being placed under the canopy. In order to ensure a constant supply of ample voltage, power lines and brooder-house wiring should be of sufficient capacity.

Dryness and Sunlight. If the brooder and the brooder house are properly ventilated, there will be little danger from excessive dampness, which tends to retard growth and spread disease. When the wind is not too strong, opening the windows to admit sunlight is an effective way to ventilate the brooder house, as well as a help in keeping the litter dry. Sunlight is a powerful disinfectant and is a source of vitamin D, which is necessary for proper bone development.

Sanitation. Many disease organisms are filth-borne, and unless reasonably sanitary quarters are maintained, losses from mortality are very liable to be excessive. The brooder house should have been thoroughly cleaned and disinfected before starting up the brooder. Cleaning consists of removing all litter and debris, then scraping the floor thoroughly, and brushing the walls clean. Next, the floors, walls, and all interior fixtures should be scrubbed with boiling-hot lye water, using 1 lb. of lye to 15 gal. of water. Third, the interior of the house should be sprayed thoroughly with any one of the following disinfectants: (1) a 5 per cent solution of cresol mixed with water at the rate of 1 pint to 2½ gal. of water; (2) crude carbolic acid mixed with water at the rate of 7 oz. per gal. of water; (3) any of the standard coal-tar dip solutions. Care must be taken not to get crude carbolic acid on the hands or clothing.

Damp litter and sick chickens tend to spread disease. After the first few days of brooding, chickens should be allowed outdoors if the weather is suitable. They should be given access to clean range on which poultry has not been kept for at least 1 year, and adult birds should not be allowed to mix with them.

Amount of Floor Space. The amount of floor space, both under the hover or canopy and in the rest of the house, has an important bearing on results secured in brooding. For each different type of brooder there are usually several different sizes. In most cases the size or brooding capacity

of a brooder is determined by the area covered by the canopy or hover. For several years brooder manufacturers have had a tendency to overrate the brooding capacity of their brooders. In addition, many poultry raisers have a natural tendency to raise more chickens with a brooder than it will accommodate to give best results in growth, feathering, and viability. These two tendencies have often resulted in retarded growth and excessive losses through overcrowding.

Under normal conditions chickens grow quite rapidly, doubling their weight approximately every 2 weeks up to about 6 weeks. For all brooders except electric ones, approximately 10 sq. in. is the minimum amount of floor space per chick under the hover or canopy that should be provided. With electric brooders, approximately 12 sq. in. of floor space per chick under the hover is the minimum that should be provided.

The amount of floor space that should be provided in the rest of the house is about ¾ sq. ft. per chick as a desirable minimum. This means that a 10- by 12-ft. colony-brooder house would accommodate about 180 chickens. If the chickens are given access to clean range as the brooding season advances, the tendency to overcrowd in the house as the chickens increase in size is greatly reduced.

From the standpoint of mortality in relation to number of chicks started per brooder, the data given in Table 31 show the decided advantange of 250 or fewer chicks per brooder as compared with flocks of larger size.

TABLE 31. PER CENT MORTALITY TO 13 WEEKS, IN RELATION TO NUMBER OF CHICKS STARTED PER BROODER
(E. C. Young, Indiana Experiment Station, 1938)

Number of chicks started per brooder.........	250 or fewer	251 to 349	350 to 449	450 or more
Per cent mortality, hatching time to 13 weeks.	5.1	11.0	15.3	19.1

Not only was there much less mortality among chickens when 250 or fewer chicks were started per brooder as compared with started units of larger size, but it was also found that fewer pounds of feed were required per pound of chicken produced.

At the same time, many broiler producers make a practice of starting 400 to as many as 1,000 chicks per brooder, depending on the size of the brooder or other method of heating and the relative amount of floor space available in the house. This is possible from a practical standpoint, because most broilers are sold at about 12 to 14 weeks of age.

Most farm-flock owners and commercial-egg producers are primarily interested in raising pullets for flock-replacement purposes. For them, about 250 chicks or less per brooder are most satisfactory.

Low Fire Hazard. Practically all brooders constitute a fire hazard. Steps can be taken, however, to reduce the hazard to the minimum. In the case of wood-burning and coal-burning brooders, the necessary precautions should be taken to prevent the stovepipe from setting the roof on fire. The hole in the roof should be made 2 in. greater in diameter than that of the stovepipe. A terra-cotta pipe or metal guard should protect the roof from the stovepipe.

Another safety precaution against fire when coal-burning and wood-burning brooders are used is to set the stove in the inverted top of a metal barrel. The top should be partly filled with sand so that live coals or hot cinders will not set fire to the litter or flooring. A cement-asbestos board extending well beyond the edges of the brooder stove is another method of avoiding the danger of setting fire to the litter and wooden floor.

Flexible leads connecting gas brooder units should be checked carefully. If oil-burning brooders are used, the oil lines must be tight and the oil-flow mechanism kept clean for smooth action.

Electric brooders, especially of the fan-ventilating type, should be kept in proper working condition at all times. Wiring for electric brooders must be heavy enough to carry the load without heating, and all connections must be tight.

COLONY-BROODING METHODS

Most farmers and many commercial-egg producers brood their chickens with colony brooders in colony-brooder houses. Since the chickens are allowed outdoors a few days after they are placed in the house, the area of land selected for brooding should be well drained and have a southerly slope.

Colony-brooder Houses. Most colony-brooder houses are either 10 by 12 ft. or 12 by 14 ft., with a wooden floor. Portable houses mounted on skids are preferable to stationary ones. Locating portable houses at least 100 ft. apart on clean range and moving them to new sites every 2 or 3 weeks during the growing season provides conditions that should promote growth and keep mortality at a minimum. An alternative arrangement consists of brooding chickens in stationary brooding houses until they no longer need heat and then moving the pullets to summer shelters on clean range. Depending upon the direction of prevailing winds, colony-brooder houses should face south or southeast in order to take the greatest advantage of winter sun. Using aluminum sheets, aluminum roll roofing, or painting the roof with aluminum helps to keep the brooder house much cooler in hot weather.

A double floor is desirable, the subfloor being made of 6- or 8-in. shiplap

on top of which is placed a layer of heavy waterproof paper and then a top floor of 1- by 4-in. or 1- by 6-in. flooring. This type of floor adds considerable strength to the building. The skids may be built as a separate unit or may be attached to the house.

The use of vertical siding reduces materially the amount of framing necessary for the walls. Insulation on the ceiling helps to maintain a uniform temperature. The sash of the windows may be arranged to slide up and down directly against 2- by 4-in. studs. Each sash is counterbalanced by means of a chain and weight, making it possible to raise or lower the sash as desired. Another arrangement for windows is to have them removable and tilting inward, supported by baffle boards, thus deflecting incoming air toward the ceiling.

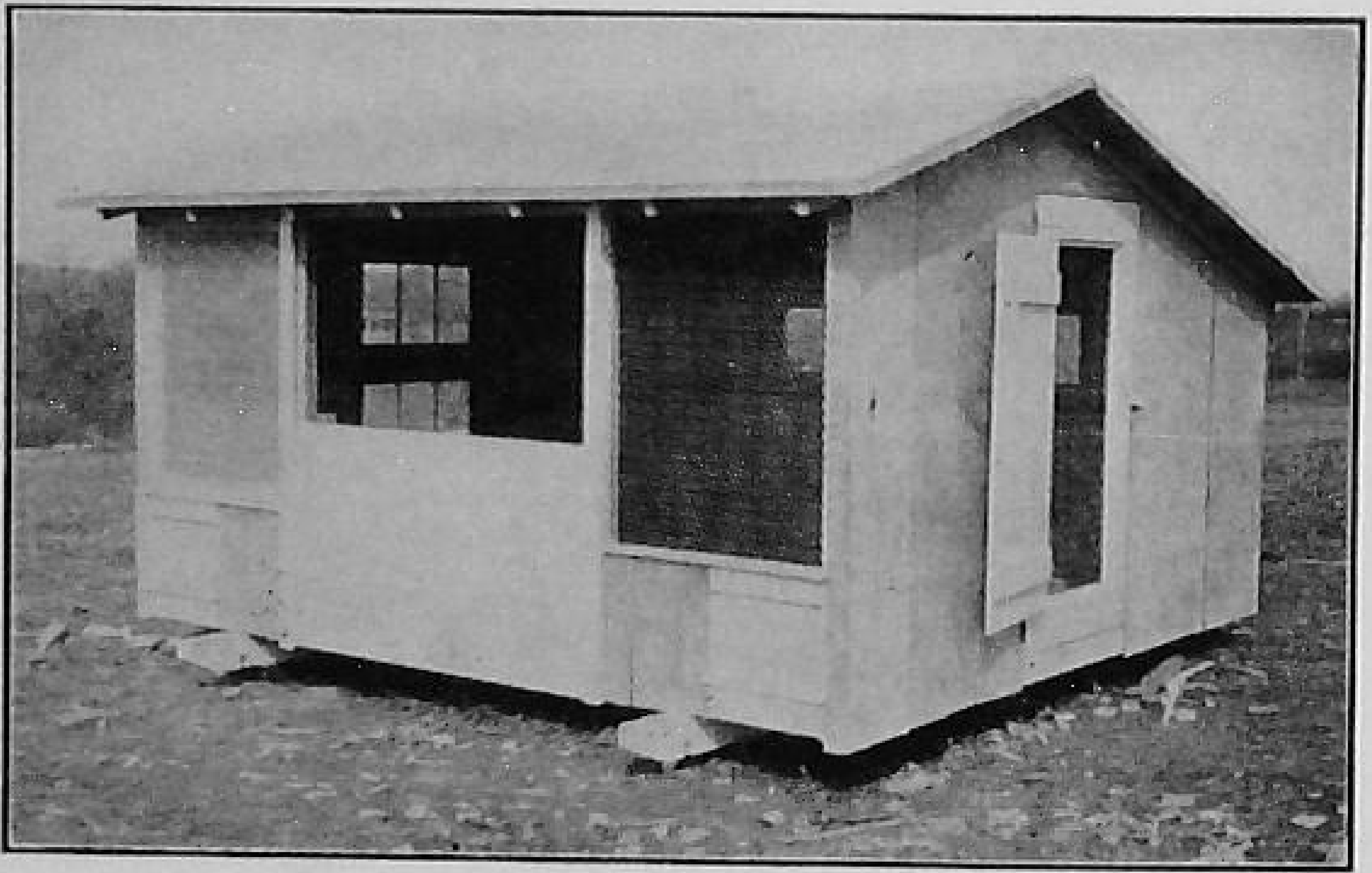

FIG. 101. A 12- by 12-ft. colony-brooder house used in Connecticut. (*Acetol Products, Inc.*)

Preparation for Brooding. The brooder house should be prepared well in advance of the brooding season. A sanitary house is necessary if losses are to be kept at a minimum, the method of cleaning and disinfecting having been described previously. The floor of the brooder house should be covered with about 2 in. of straw, shavings, or a good commercial absorbent litter. Chopped corncobs, cane pumice, and cottonseed hulls may be used. Peat moss is used extensively by broiler growers. After the chickens are about 3 weeks old, hydrated lime may be added to the litter at the rate of about 10 to 15 lb. per 100 sq. ft. of floor space. Stirring the lime thoroughly with the litter helps to keep it dry. About 2 in. of new litter should be scattered on top when needed. Built-up litter is apparently not advisable for southern sections of the United States because of the danger of chicks becoming infested with internal parasites.

Brooder thermostats should be tested by immersing them in *warm* water (not *hot* water) before starting the brooder. The brooder should

be started 3 or 4 days before the chicks are ready to be placed in the brooder house. Chicks that vary more than about 1 week in age should not be brooded together, because the younger chicks are very likely to

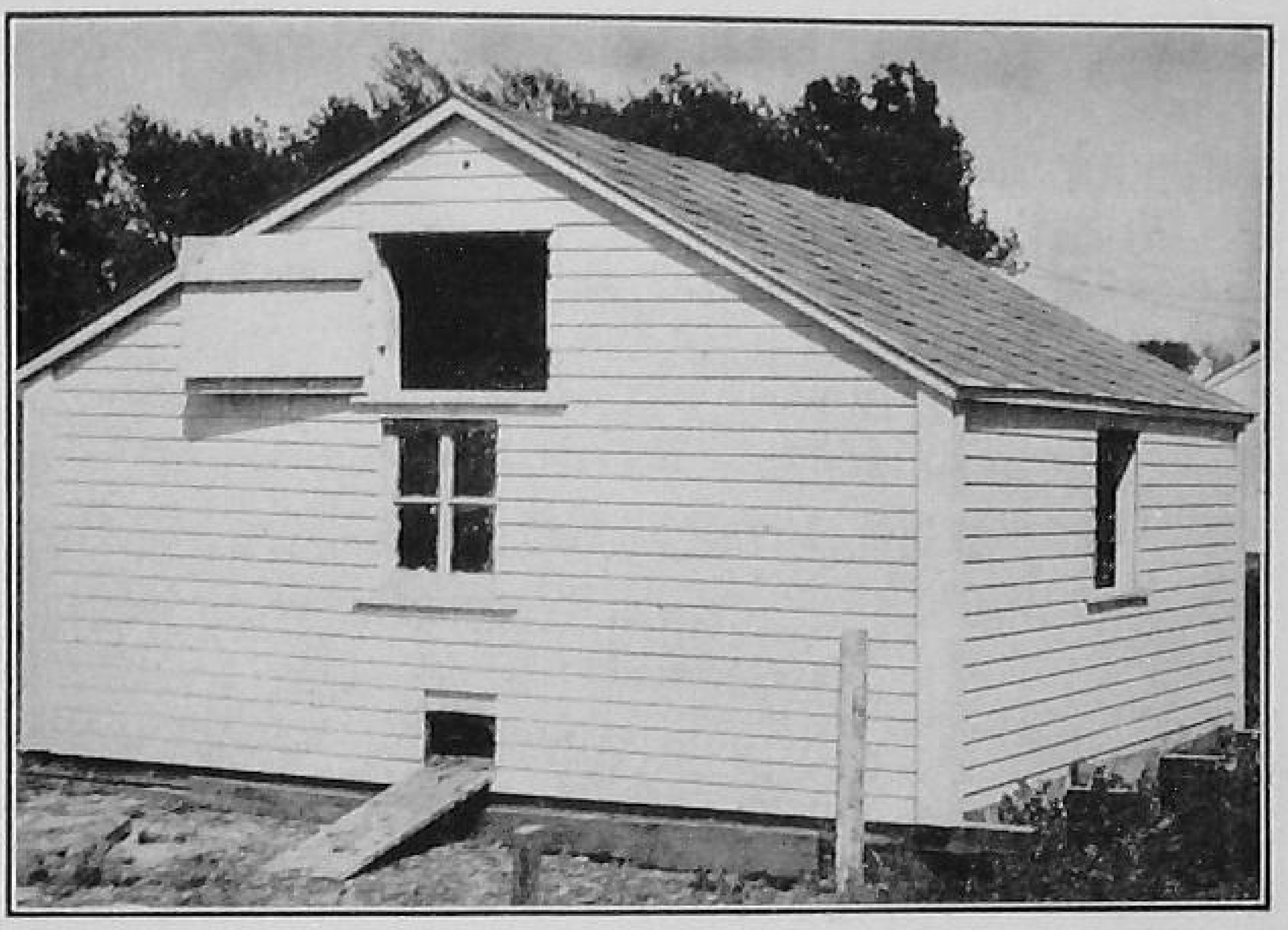

FIG. 102. The rear end of a colony-brooder house in Iowa, showing a ventilating door at the rear end and a window on one side. (*Iowa Agr. Ext. Service.*)

get insufficient feed and are also likely to be trampled under by the older birds.

Before placing the chicks under the brooder, a guard of stout cardboard, or fine-mesh poultry netting with burlap attached, may be placed

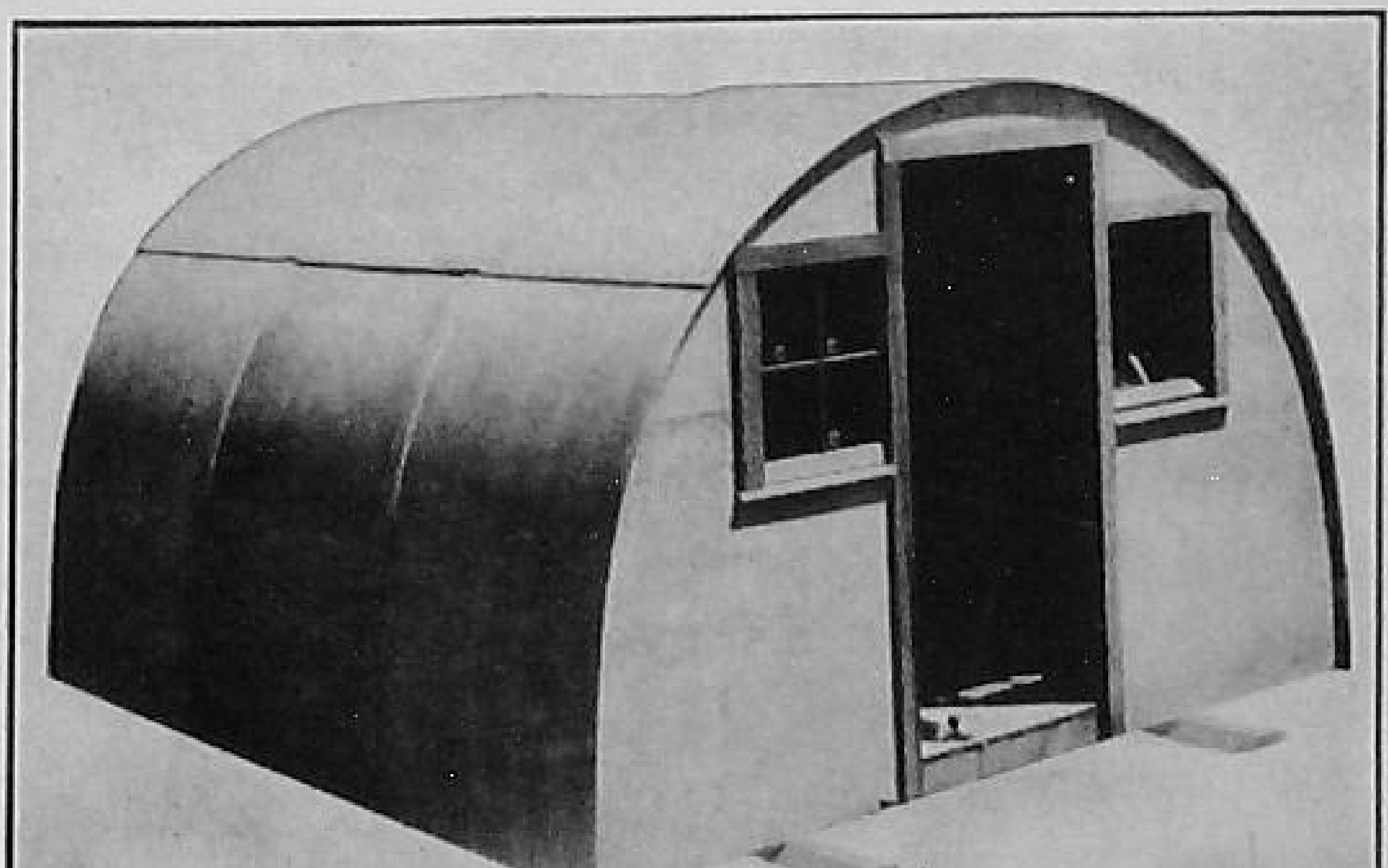

FIG. 103. A brooder house built of sheet material made of asbestos and cement. (*Johns-Manville.*)

around the brooder at a distance of about 2 ft. from the hover. This guard keeps the chicks near the source of heat, so that they will readily learn the source of heat and will become accustomed to going under the

hover to avoid becoming chilled. The guard should be moved farther and farther away from the hover after a few days and discarded entirely when the chicks have learned to return to the source of heat.

Hopper Feeding Space. For the first few days of brooding, chickens may be fed in shallow boxes or pans, or cup-flats used in packing eggs may be used. After chickens are about 1 week old, small feeders made of metal or wood are usually used. They should be easy for the chicks to feed from, prevent the chicks from getting into the feeder to soil the feed, and prevent waste.

Chickens are usually fed mash mixtures only for the first few days, so that there is no chance of scratching for feed in the litter. For about

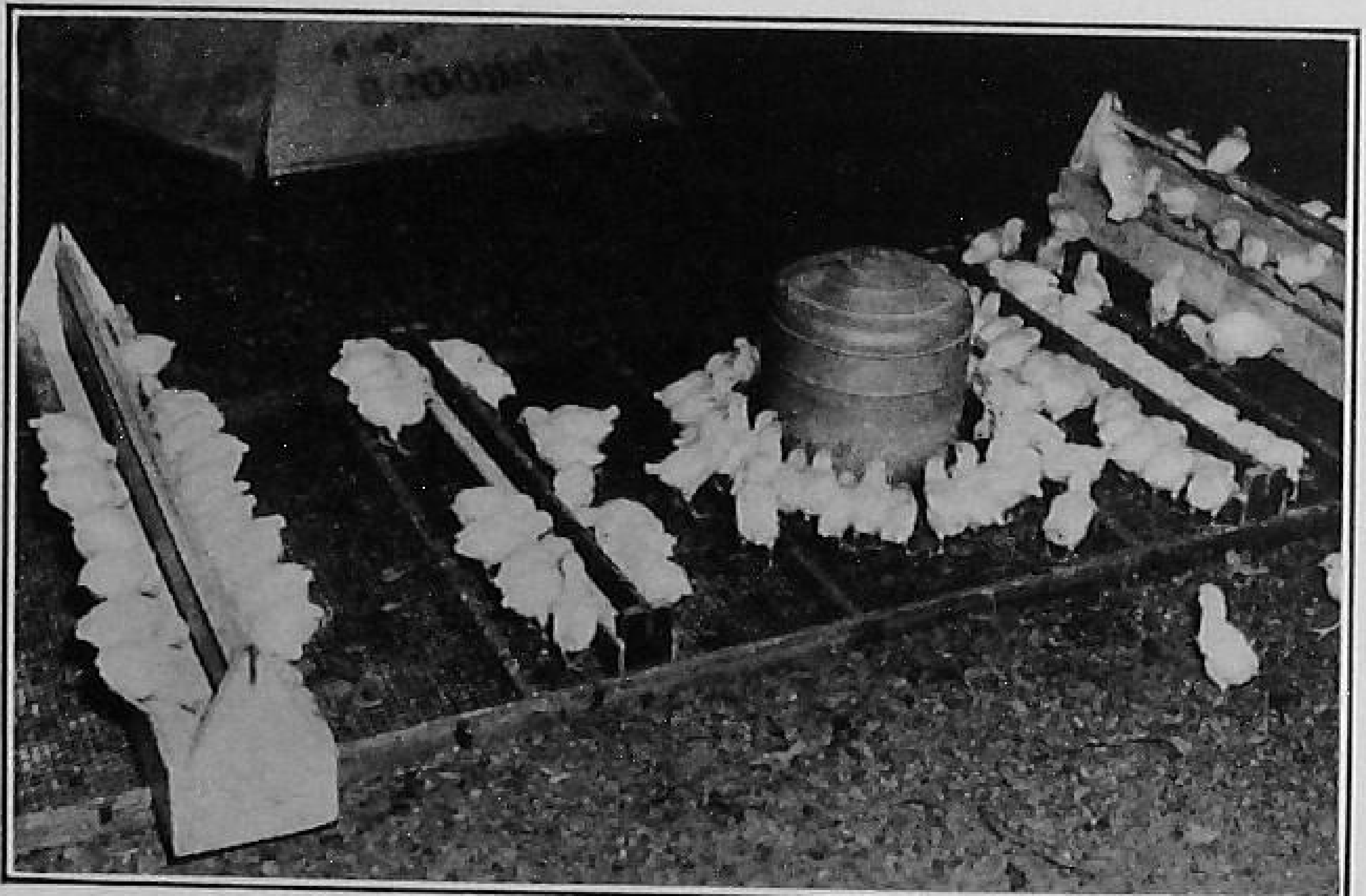

FIG. 104. Feeders and waterers on wire platforms to help keep the feed and water clean. (*Wash. State Agr. Ext. Service.*)

the first 2 weeks, 1-ft. length of a double-side feeding hopper is needed for every 20 chickens (1 ft. on each side of the hopper for 10 chickens). Beginning the third week through the eighth week, 1-ft. length of a double-side feeding hopper for every 10 chickens is needed. After the eighth week, 1-ft. length of hopper for every 6 or 7 chickens is needed. Laying a strip of ½-in.-mesh hardware cloth on top of the mash in the hopper will help to prevent feed wastage.

As soon as the chickens are large enough, it is a good practice to place the mash hoppers on wire platforms in order to avoid contaminated feed. On many commercial-broiler plants, automatically controlled mechanical feeders are used. Much labor is saved in feeding the chickens. During the last 3 or 4 weeks before marketing time, it is well to put extra mash in mash hoppers.

Water Containers. Containers for water and milk should be large enough to hold a reasonable supply, not easy to upset, convenient for the

chickens to drink from, yet prevent them from getting their feet into the liquid. Containers with flat tops permit the chickens to stand on them and contaminate the liquid with their droppings.

The liquid containers should be placed on wire platforms in order to keep the chickens out of the damp litter surrounding the containers.

In a warm brooder house and during warm weather, chickens consume considerable quantities of water; so it is most important that the water containers should never be allowed to become empty. On many farms and commercial-poultry plants, it would be a matter of considerable

FIG. 105. The chicks are given range, but for the first few days are confined to a limited area in front of the brooder house. (*U.S. Dept. Agr.*)

economy in labor to provide running water and automatic water fountains, especially for growing stock on range.

All liquid containers should always be kept in a thoroughly clean condition, because they are one of the most important sources of the spread of certain diseases. They should be washed daily and disinfected weekly.

Access to Outdoors. When the chickens are a few days old, they should be allowed outdoors. This not only reduces the chances of overcrowding within the house but also gives the chicks full access to sunlight. For the first few days a temporary fence of narrow chicken netting should extend from each corner of the front of the colony-brooder house to enclose a small area. This prevents the chickens from wandering too far from the brooder house and getting lost. The importance of clean land for raising chicks cannot be overemphasized. Succulent green grass or other vegetation supplies nourishment and provides a more sanitary area than bare land.

Sun Porches. Where the land available for brooding chickens is limited and the soil has become contaminated with disease organisms and the eggs of internal parasites, the use of wire-bottomed sun porches is strongly recommended.

The wire-screen sun porch is an outside enclosure next to the brooder house. It is usually about half the area of the floor inside. The frame for the bottom is made of 1- by 4-in. boards set edgewise and spaced 2 ft. apart. This is covered with 34-in.-square-mesh hardware cloth, made of No. 15 or 16 gauge wire, 24 or 28 in. wide, the narrow width being preferable. The frames may be made in sections, the size depending upon the number of birds to be accommodated. For a 10- by 12-ft. brooder house, a frame 6 by 8 ft. is used. Front and end panels are 24 in. wide and are made of 1- by 3- or 4-in. strips, covered with 1-in.-mesh poultry netting. The top panels may be made 2, 3, or 4 ft. wide. The front top panel is hinged so it can be opened easily when desired. The floor of the screen sun parlor may be placed 10 or 20 in. above the ground, so that the droppings can be removed by a scraper, or the frame may be set close to the ground and removed during the process of cleaning.

In order to ensure that all the birds take advantage of the sun porch, they should be fed and watered on it. The mash troughs should be protected from rain by slanted boards, hinged so as to turn up when food is being put into the troughs.

Early Roosting. Teaching the chickens to roost beginning about the fifth week has two distinct advantages. The tendency to overcrowd on the floor is reduced, and the chickens are assured of an adequate supply of fresh air at night. At first, the roosts should be placed near the hover so that the chickens will learn readily to take to the roosts. Later they can be moved to the rear of the house; in fact, roosts hinged to the back of the house are often used from the beginning. The roosts, made of 2 by 3-in. pieces laid flat, should be about 8 to 14 in. apart, depending on how long the chickens are to be kept in the house. Wire netting may be placed under the roosts to keep the chickens from scratching in the manure. Relatively wide roosts are better than narrow ones, because the latter may have a tendency to cause crooked keels.

Separation of Sexes. Early separation of the sexes is highly desirable to provide plenty of space for the growing pullets, since the primary objective of most poultrymen is rearing pullets as replacements for the laying flock. Where broiler production is the primary objective, the pullets and cockerels are reared together until marketing time, unless "sexed" chicks are purchased. Where the rearing of pullets is the primary objective, they should be moved to another house or summer shelter, with access to clean range as soon as they can do without heat.

The cockerels may be left in the original brooder house, to be sold as broilers or fryers. The sooner the cockerels are removed from the pullets, the greater are the chances that the pullets will develop properly into profitable layers. The sexes are usually separated at from about 5 to 8 weeks of age. In Leghorns the sexes should be separated earlier than in general-purpose chickens.

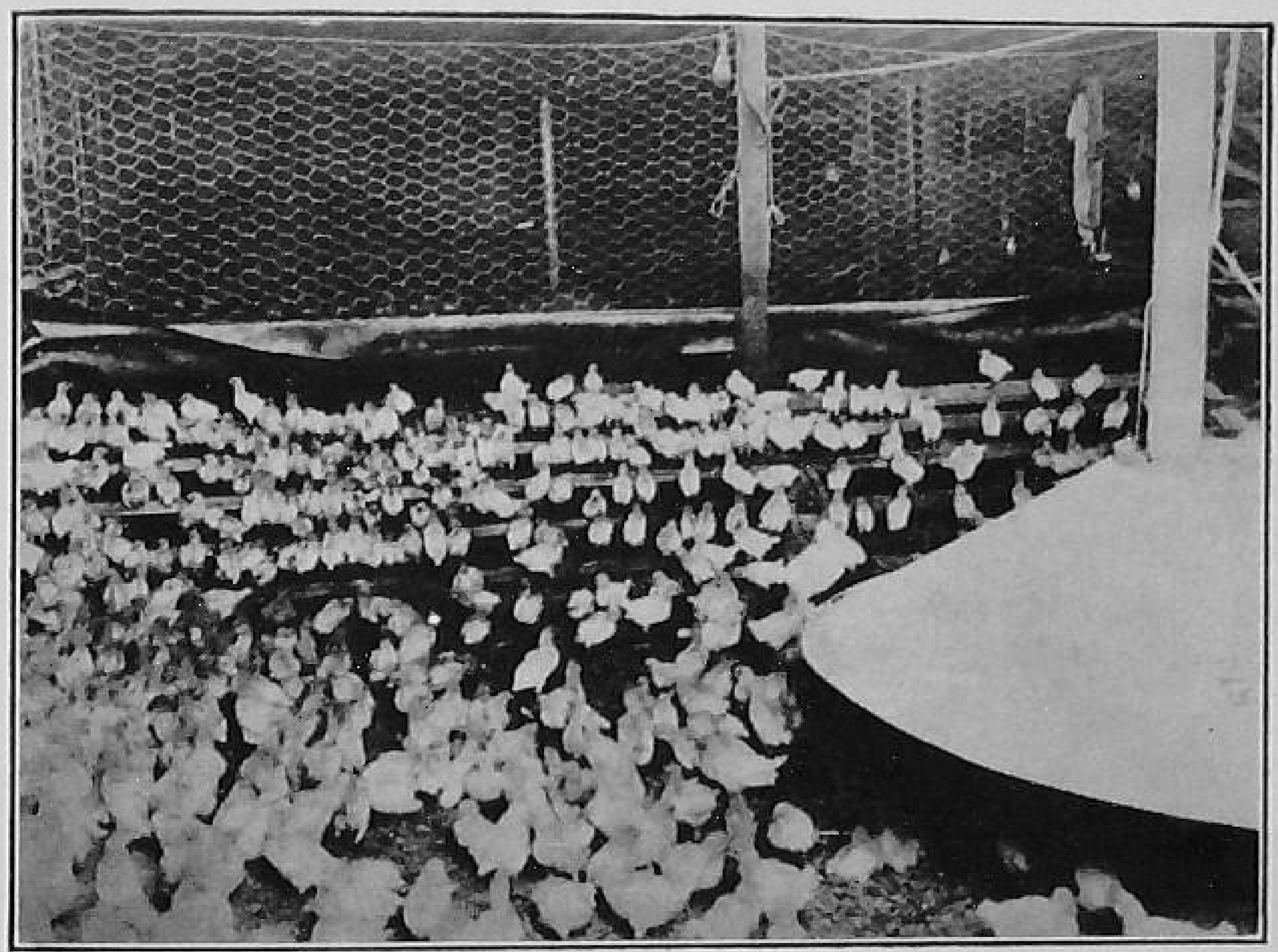

FIG. 106. Teaching the chicks to roost early is not only the best way of ensuring their comfort but also reduces mortality. (*U.S. Dept. Agr.*)

The sexes can be distinguished at a relatively early age, especially in Leghorns, by the larger sized comb and wattles, longer tail feathers, and stouter shanks which have larger scales in cockerels than in pullets.

CONTINUOUS-BROODING METHODS

There are three kinds of continuous brooders used by large-scale producers. In most cases the brooder rooms are heated by means of hot-water pipes. In a few cases hot air is conducted through ducts to the brooder rooms.

Where several thousand chickens are to be raised annually, the continuous-brooding method has certain advantages over colony-brooding methods. The greatest advantage is in the saving of labor. Also, fuel and operating costs and depreciation are relatively lower. On the other hand, the cost of installation is relatively high, and since large numbers of chickens are brooded together, rate and uniformity of growth are frequently not so good as in the case of colony brooding.

Most of the brooder houses in which the continuous method of brooding

is used are from 20 to 50 ft. wide. A boiler is used, located at one end of a medium-sized house or in the center of a large-sized house. Heat radiation is affected by the size and kind of pipes used. The capacity of the boiler should at least equal the radiation of the pipes, and many poultrymen allow for 100 per cent more boiler capacity than called for by radiation. Expansion tanks located above the boiler and air vents inserted in a closed system to prevent the system from becoming air locked are parts of a complete hot-water brooding system. Thermostatically controlled circulating pumps aid greatly in maintaining a uniform temperature throughout the entire house. The advice of a competent

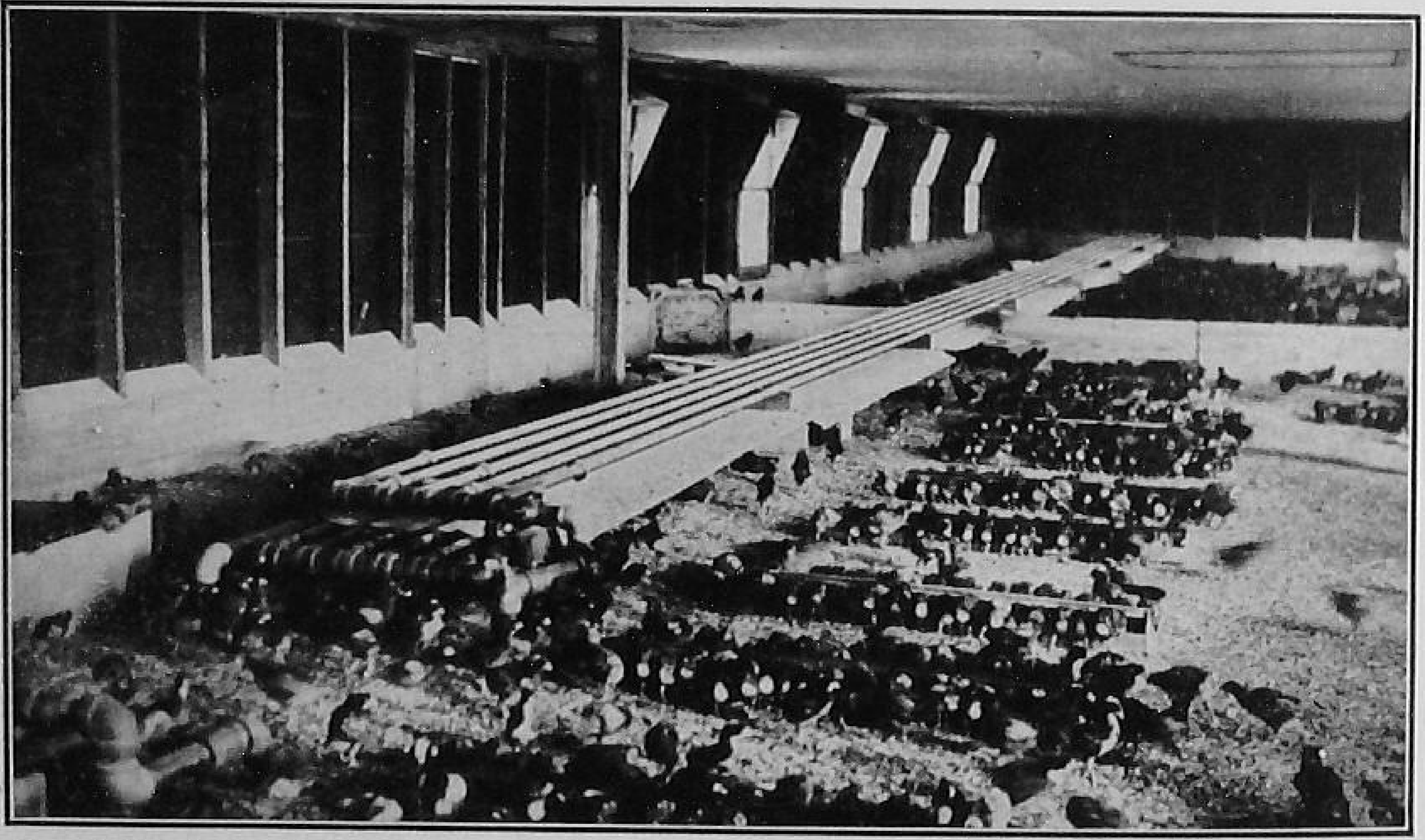

FIG. 107. A continuous hot-water hover for brooding large numbers of chickens. (*Pa. State Coll. Ext. Service.*)

engineer should be sought before installing a hot-water heating system. A well-insulated house tends to conserve heat and reduces the cost of fuel. Careful thought should be given concerning the amount of ventilation needed in the brooder house.

The continuous-brooding method of brooding is quite popular with many broiler producers.

Hover Method. Hot-water pipes run the length of the brooding house and are about 8 to 12 in. above the floor. A hover, made of tar paper or sheet metal, covering the pipes conserves the heat so that the chickens are provided with heat in the same manner as in the case of portable brooders.

Apparently, one of the best places to locate the pipes is from 5 to 8 ft. from the rear wall. This provides better ventilation under the hover

than when the pipes are located adjacent to the rear wall of the brooder house. Also, there is less danger of the chicks crowding.

Additional heat for the brooder room is sometimes provided by running pipes immediately above the hover or along the rear wall of the brooder house.

Warm-room Method. Hot-water pipes run the length of the brooder house along the rear wall and along the front wall of a long house or across the ends of a short house. With this method of heating it is particularly important to have well-insulated rear and end walls.

Radiant-heat Method. Hot-water pipes running lengthwise of the brooder house are buried in concrete to a depth of from 1 to 3 in. This method of brooding is radiant heating.

Iron, brass, steel, or copper piping may be used. The size of pipe to use depends partly on which of the above kinds is chosen. Wrought-iron piping of 1¼-in. size has been found to be satisfactory, and it should be welded rather than threaded. The piping is laid at intervals of about 12 to 14 in. Copper tubing ½ or ¾ in. can be soldered, thus saving labor in installation, and it should last almost indefinitely. Copper tubing should be spaced from 5 to 12 in. apart, depending upon the size of tubing used.

The concrete in which the piping or tubing is embedded may be laid on solid dirt, sand, gravel, or a subbase of concrete. The piping should not be laid on cinders. The system should be thoroughly tested before the concrete is poured around the piping or tubing. The piping or tubing should be cold when the concrete is poured. The concrete floor is strengthened, and there will be fewer cracks if welded mesh wire is placed in the concrete. The expansion of the concrete against the ends and sides of the building must be provided for by installing insulation material at the proper places. Only a limited amount of litter should be used, and the brooder-house rear and end walls should be insulated.

In order to avoid excessive heat loss from the heated concrete floor to the walls of the brooder house, it is advisable to insert an insulating strip having a moisture-resistant covering between the concrete floor and the wall. This same type of insulation could also be laid under the concrete floor if desired.

An automatically controlled ventilating system is usually installed. The outside ventilating louvers should be kept closed for about the first 2 weeks. After that, ventilation is necessary, even when the outside air temperature is relatively cold.

When the chicks are placed in the brooder house, the temperature at the surface of the floor should be about 95°F. The air in which the chicks are moving will have a temperature of about 90°F. After the first week,

the air temperature is reduced about 2°F. every week to about the eighth week. After 8 weeks, the air temperature may be maintained at about 70 to 75°F.

Before installing a radiant-heating system, a competent engineer should be consulted. According to some commercial-broiler producers,

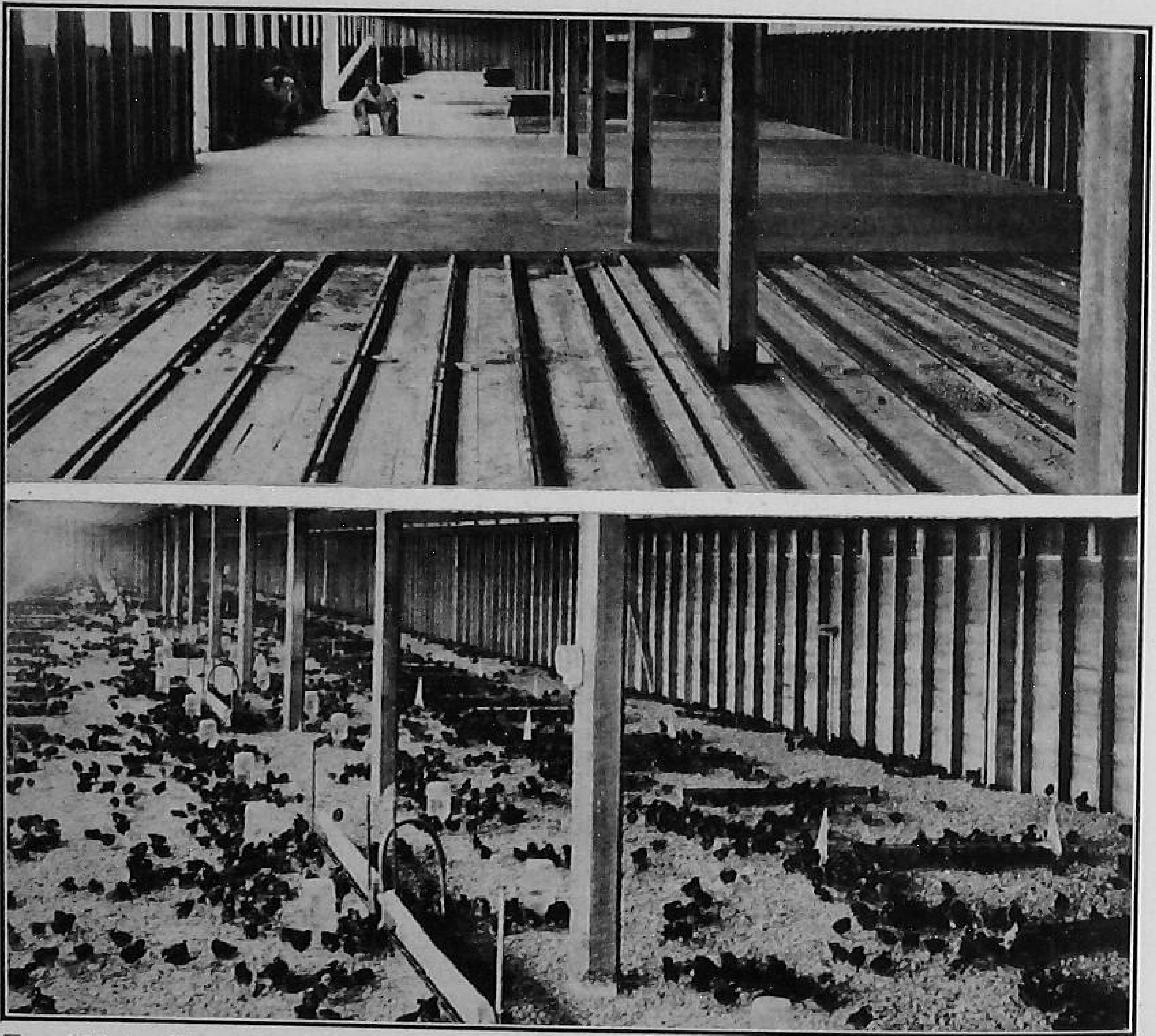

FIG. 108*A*. Top, the radiant-heat method of brooding, showing pipes embedded in concrete. Bottom, thousands of chickens being brooded together in same brooder house as above after it was completed. (*Pa. State Coll. Ext. Service.*)

one objection to the radiant-heat method of brooding is that it takes too long to raise or lower the temperature of the brooder house whenever a change in temperature becomes necessary. Also, the air in the house is apt to be dry.

Warm-air Duct-type System of Heating. In Fig. 108*B* is shown the interior of a modern commercial brooder house in which the duct-type system of distributing warm air is employed. The house is 48 ft. wide by 312 ft. long and accommodates 21,000 broilers. A centrally located boiler with two automatic stokers produces steam which is piped in 3-in.

pipes to heat exchangers, where two centrifugal fans blow air over the steam pipes into ducts which carry the warm air lengthwise throughout the house. The ducts are reduced in size as they extend away from the boiler and at about 15-ft. intervals the warm air is forced through 8-in. pipes to about 12 or 18 in. above the floor, each downpipe being equipped with a damper. The blowers in the heat exchangers are regulated by thermostats, which are set to maintain the proper temperature (for the

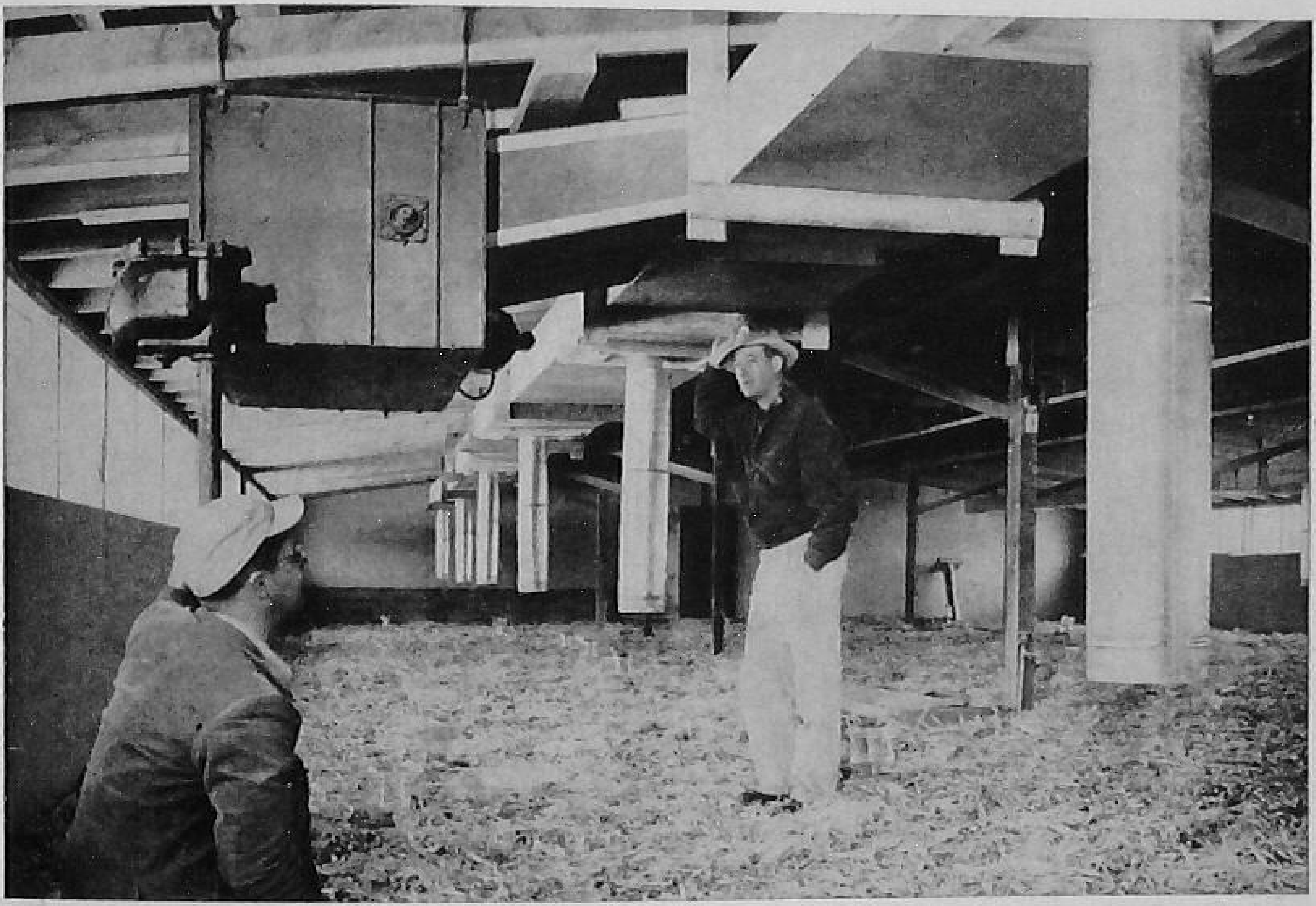

FIG. 108*B*. The interior of a warm-air-heated commercial brooder house in Maryland in which the duct-type system of distributing warm air to outlets 12 or 18 in. above the floor is employed. The exterior of this house is shown in Fig. 115. (*Photograph by Laird Wise, courtesy R. E. Walsh.*)

chickens) at floor level. The heating system is provided with a humidifier to provide the proper humidity. The system can also be used for cooling the brooder house in hot weather.

REARING YOUNG STOCK ON RANGE

Whether chickens are brooded under colony- or continuous-brooding methods, if the pullets are intended as replacements for the laying flock, the pullets, and also the cockerels saved for future breeding purposes, should be reared on clean range.

Summer Shelters. If the colony-brooder houses are not located on the range, it is a good practice to separate the pullets from the cockerels shortly after no more heat is needed in brooding and move the pullets to summer shelters on range. The cockerels may be kept in the brooder

houses until ready to be sold as broilers or fryers. Cockerels that are kept to be used as breeders are usually reared with the pullets.

Summer shelters should be of durable construction because they should be moved from time to time. All sides are usually wire netting. If protection is needed against cold winds, building paper, burlap sacks, or plywood may be placed on one, two, or three sides. Stout skids or runners should be attached firmly to the framework.

The wooden framework and skids of the shelter should be sprayed every year with either creosote or carbolineum and equal parts of kerosene. This mixture not only tends to preserve the wood but serves as a deterrent against red mites.

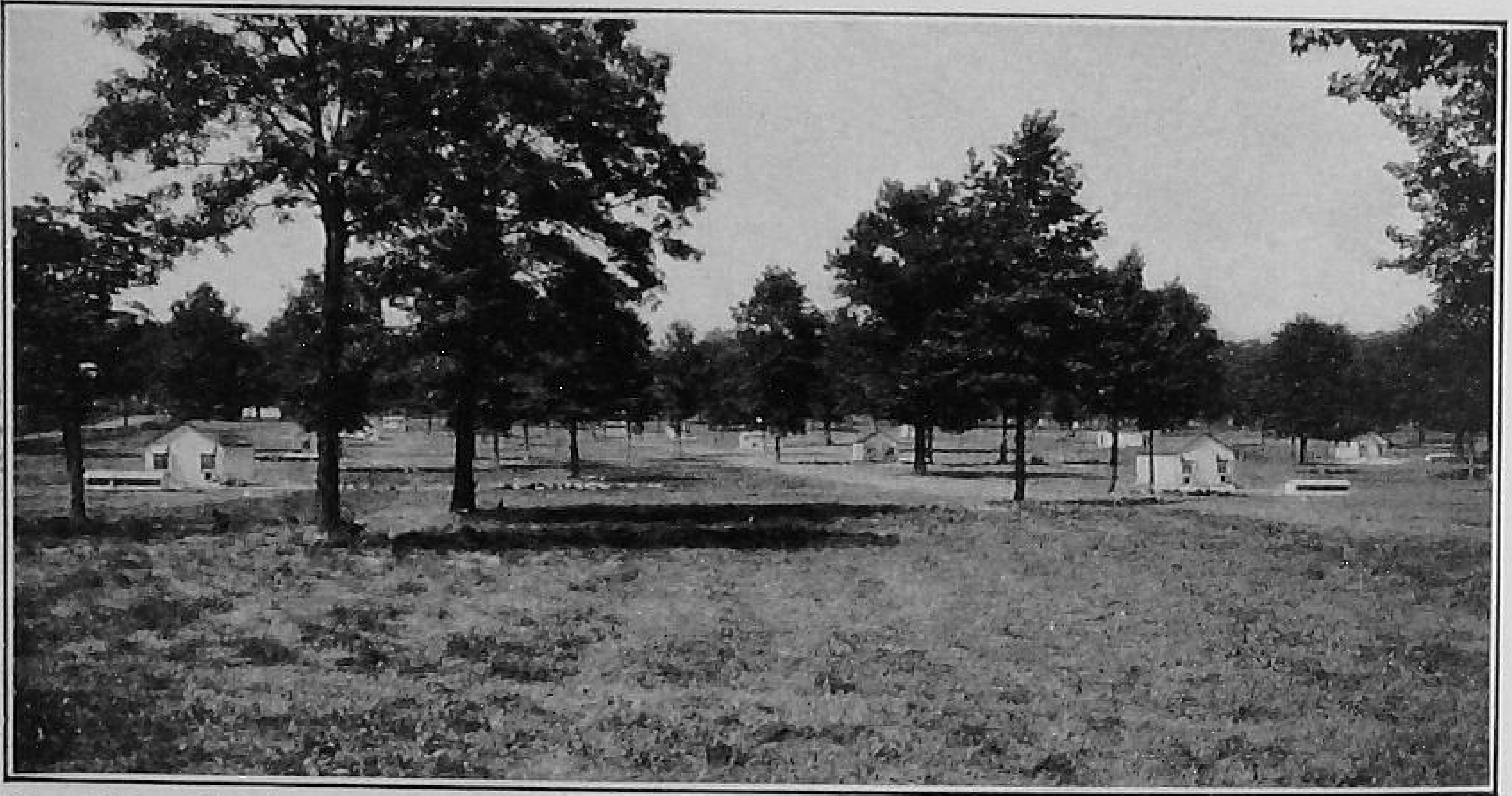

FIG. 109. Good range and plenty of shade are important factors in the successful rearing of pullets. (*U.S. Dept. Agr.*)

A shelter 8 by 12 ft. is large enough to accommodate about 100 pullets and can be moved readily.

Succulent Pasture. There are probably no substitutes for sunshine and green grass when it comes to raising chickens. Sunshine helps to keep the chickens healthy and promotes proper development of the bones. A good grass range provides succulent green feed, reduces the feed bill, and the nutritive value of the grass grown on such ranges is enriched by the poultry manure. Rearing chickens on clean range lessens the chances of picking, cannibalism, parasitic infestation, and disease infection. Above all, chickens should not be kept on bare ground, especially if filthy water puddles are present.

Summer shelters should be located about 200 ft. apart on the range and should be moved at least once a month. The range should provide ample shade and an abundance of grass or other succulent green crop

throughout the summer. On a permanent grass range, there should not be more than 300 pullets per acre. A bluegrass sod is excellent. Ladino clover is gaining in popularity in many parts of the country. Oats, wheat, barley, rye, clover, smooth brome, redtop, or Sudan grass may be sown at different intervals throughout the summer to maintain a constant supply of succulent green feed. The pasture can be kept in a succulent state by keeping it clipped short. By adopting a proper crop-rotation system and moving the range shelters every month or oftener, it is possible to raise as many as about 800 chickens per acre. It is very important, however, to keep the strips of ground on which the green crops are grown cultivated regularly and resown to seed as soon as the leaf stage in

FIG. 110. A satisfactory type of Michigan summer shelter. *(C. H. Jefferson and E. R. Hancock, Mich. State Coll. Ext. Service.)*

development is passed. Successive strips of oats should be alternated with strips of corn and rape and with strips of other green crops. For pasturing purposes, about 6 bu. of cereal grains per acre should be sown.

One plan that has been found satisfactory in certain parts of the country is to have strips of grass sod 30 or 40 ft. wide on which the range shelters are located; between the strips of sod may be grown any quick-growing herbage adapted to the region. Strips of corn will provide shade.

Predaceous Animals. Flock owners sometimes suffer considerable loss from attacks by predaceous animals such as foxes, hawks, and crows. Chickens on range may be given some protection by placing near the range shelter an all-night flare, such as is used on highways to warn motorists of stalled trucks or temporary obstacles. Hawks and certain other birds may be trapped in different styles of traps.

Losses from foxes frequently reach serious proportions, and the problem of dealing with these enemies presents a serious problem. Bounty systems, hunting, trapping, and den hunting are common methods of control, the last method being the most effective. The following methods of preventing losses are recommended: (1) tethering dogs to kennels or to wires strung between poles at various places on the range; (2) a two-wire electric fence, the wires being 6 and 12 in. above the ground; (3) a 5-ft. fence, with 2 ft. buried underground; (4) spraying a strip of ground

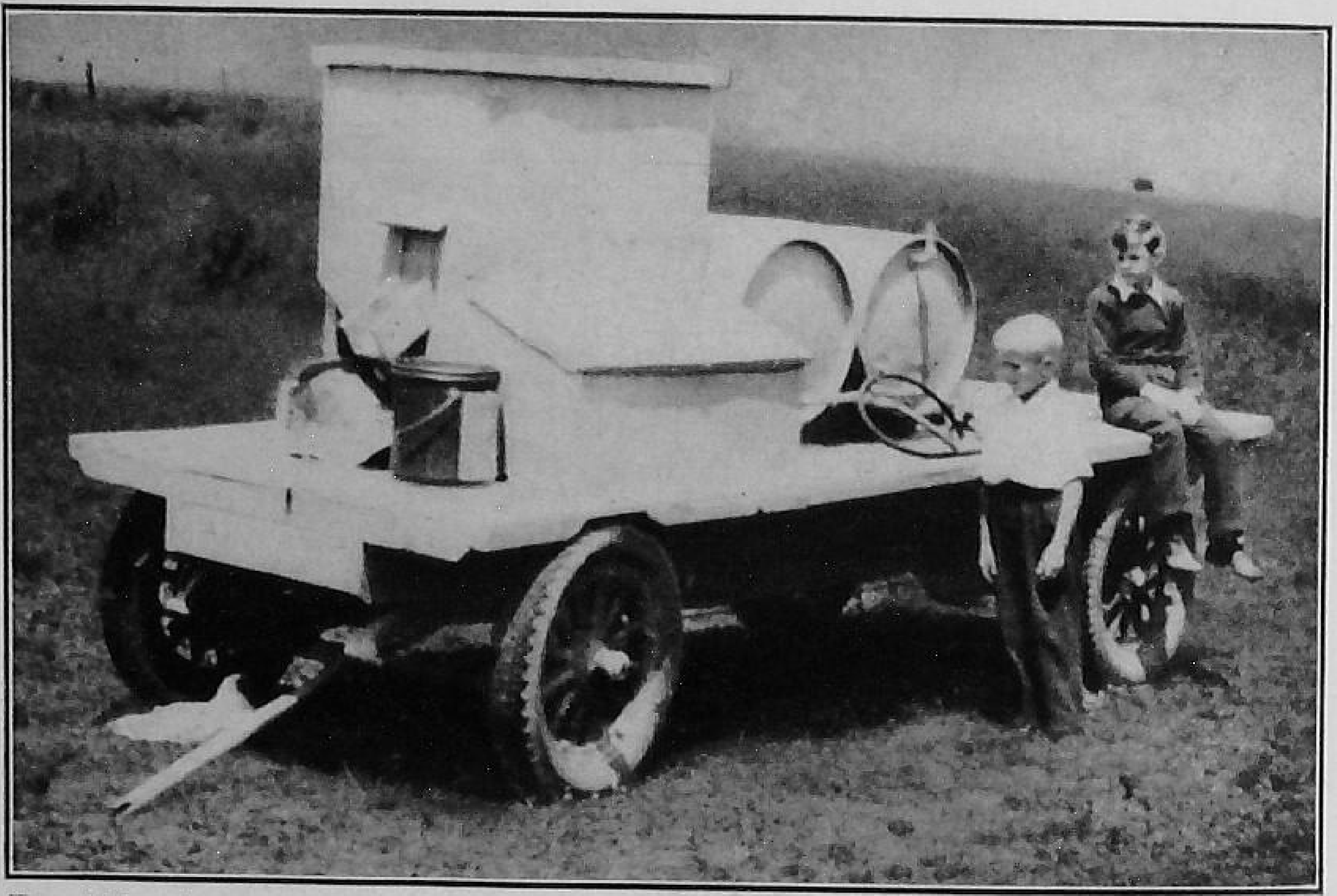

Fig. 111. A range-supply trailer on a New York poultry plant saves time and labor in feeding and watering chickens on range. (*L. M. Hurd, N.Y. State Coll. Agr.*)

2 ft. wide around the entire range area with a repellent mixture consisting of 1 part spirits of turpentine and 20 parts crude furnace oil.

Laborsaving Practices. Few poultrymen realize the extra miles walked and time spent needlessly in caring for chickens on range because of lack of organizing the chore route and because of a lack of proper facilities. Piping water to the range saves much time and labor. If this is not possible, a small tank or other water container may be hauled to the range by a tractor. The tractor may also be used to haul mash to the range. With a truck or a tractor, crates of chickens can be hauled on a sled, thus saving labor in lifting.

Regular Culling. Poorly developed birds in flocks of growing chickens may be due to the low quality of breeding stock from which they were obtained, or to faulty diets, or to improper management. If all three

of these unsatisfactory conditions prevail in the same flock, it is almost certain to be an unprofitable flock. In fact, the amount of culling that should be done in a flock of growing chickens is a fair index of the quality of baby chicks secured and the methods of management employed.

The three outstanding advantages in culling growing stock from time to time are (1) a saving of feed; (2) a tendency to prevent the spread of disease; (3) a more uniform flock as the final result. Chickens that remain stunted in growth are unable to utilize their feed efficiently, with the result that the longer they are left in the flock the greater the amount of feed wasted. Some diseases spread from sick to healthy chickens

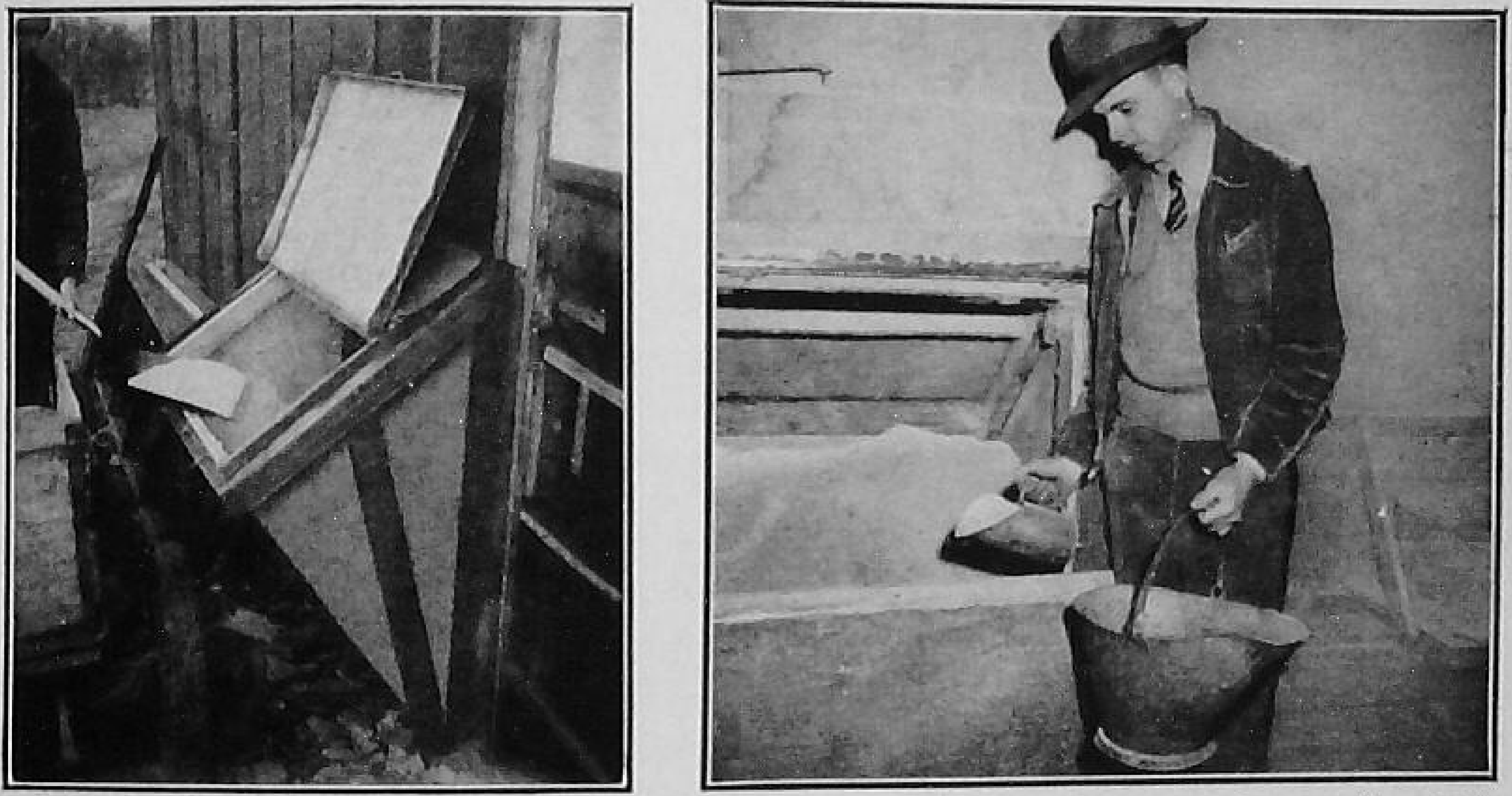

Fig. 112. Paul Pippit of Case County, Mo., fills feed-storage bin from the outside of his brooder house, thus saving time in daily feeding. *(Photograph by Mo. Agr. Ext. Service, courtesy of Farm Journal.)*

very quickly, so that it is very important to remove sick chickens from the flock as soon as they are noticed. Then again, if diseased chickens are not culled from the flock promptly, the litter in the house and the soil adjacent to the house may soon become contaminated with disease organisms. Prompt culling of sick chickens reduces the danger of contamination. Finally, if undeveloped and diseased chickens are culled from time to time throughout the growing season, the rest of the flock will be more uniform in appearance and size. This is important in marketing broilers or other classes of live chickens, because a group varying in size usually has to be sold at a discount.

There are several symptoms indicating lack of vigor in growing stock. If young chickens look dumpy and tend to huddle in a corner, it is a sure sign that they are either chilled or sick. Droopy feathers indicate disease. Plumage lacking its normal luster, characteristic of healthy birds, indicates sickness. An eye that is dull and sunken usually indicates lack of

inherent vigor or the presence of disease. It is very important to cull chickens showing gray eyes with irregular pupils.

In practically every flock of growing chickens, there are some birds that are poorly feathered up to 6 or 8 weeks of age. Poor feathering is sometimes due to certain deficiencies in the diet or overcrowding in the brooder house, but is generally due to breeding. All poorly feathered birds should be marketed.

The body should be well proportioned, with good length and width and fair depth in proportion to the length of the shank. The keel should be practically parallel with the back. All birds with crooked keels and those with extremely narrow bodies should be culled and marketed at the most advantageous size.

In order to lay well during the first laying year, pullets must possess an abundance of vigor. This is indicated by a bright, prominent eye, a stout beak on a broad head, bright-yellow shanks, lustrous plumage, and good fleshing. Pullets that show any indication of lack of vigor, especially if they have gray eyes with irregular pupils, should be culled rather than put in the laying house.

From Range to Laying House. It is best to move pullets to the laying house about 2 weeks before they commence laying. In almost every flock of pullets on range, however, there is nearly always some variability in the age at which they are ready to start laying. A few pullets may have attained sexual maturity 2 or 3 weeks before the rest are ready to be moved. It is a good practice to have a small nesting house on the range in order that these early maturing pullets learn to go to the nests. This tends to avoid dirty eggs, and the eggs are all in one place at collecting time.

Moving the pullets from the range to the laying house should preferably be done on a cool day and with as little distrubance to the birds as possible. The catching crates should not be overcrowded, or some pullets are liable to be smothered. If the laying house contains two or more pens, it is well to sort the pullets according to development.

BATTERY-BROODING METHODS

Brooding chickens in electrically heated batteries is employed mostly by broiler producers living near towns and cities. The birds are usually sold locally, dressed and drawn, as well as in the cut-up form. Chickens that have been raised in batteries and are shipped alive a considerable distance to market usually shrink excessively in weight. Pullets that are to be raised on range for flock-replacement purposes should not be brooded in battery brooders.

As compared with the colony-brooding method, the battery-brooder

method makes possible the raising of a large number of chickens in a concentrated space and there is usually less danger from mortality. On the other hand, under the battery method, the diets have to be more carefully balanced and methods of management must be more carefully controlled.

Equipment. The principal equipment for raising broilers in batteries consists of starting batteries equipped with electric-contact-type heaters, growing batteries with or without heaters, and finishing batteries. In the case of all three types of batteries, the feed and water troughs should be adjustable. The design of the trough should be such as to waste as little feed as possible. In each case, the chickens should be able to stand up comfortably. All batteries should be made of heavy galvanized or rustproof metal and should be of sturdy construction.

Starting batteries are designed for brooding chickens up to about 4 weeks. They are built from 3 to 5 decks high. Growing batteries are designed to accommodate chickens from about 4 to about 7 or 8 weeks. For the same number of chickens started in starting batteries, about twice as much battery "floor" space is required in the growing batteries. Finishing batteries carry the chickens from about 7 or 8 weeks to marketing time, which is usually at 10 to 12 weeks of age. In some cases growing batteries are not used, the chickens being transferred from the starting to the finishing batteries.

Space per Chick. The following are the minimum number of square inches of "floor" space required per chick: up to about the fourth week, 20; up to about the eighth week, 45; up to about the tenth week, 55; up to about the twelfth week, 70.

Building Requirements. Many different types of buildings are used to house the batteries. The shape of the building should be such as to accommodate the batteries with sufficient space between each battery and between the batteries and the walls and yet without considerable waste space. A building about 30 ft. long and 20 ft. wide will accommodate a sufficient number of batteries needed to produce approximately 150 broilers per week.

The floor of the battery building should be of concrete, easy to clean, and sloped to drains. The ceiling of the battery room should be 10 ft. above the floor, and there should be 3 or 4 ft. between the ceiling and the top of the battery. Between the bottom of the battery and the floor there should be a space of at least 18 in. The roof should be of such design and construction to reflect heat, two coats of asphalt-base aluminum being desirable. The building should be well insulated. All interior surfaces should be of durable construction, easy to clean, impervious to moisture, and able to withstand strong disinfectant solutions.

Enough light for the chickens to see to eat and drink is much better

than too much light, which is apt to make the chickens nervous and excitable. Artificial lighting, 14 hr. per day, should provide uniform illumination on feeding and watering troughs. Windows placed along the east and west sides provide approximately equal illumination throughout the day. They should be slanted and baffled if necessary in order to prevent drafts of air from striking the birds.

In order to remove excessive hot air from the room, especially during the summer months, it is necessary to have fan-type ventilators in the

Fig. 113. These battery brooders will accommodate chicks for about 6 weeks. (*Kerr Chickeries.*)

peak of the roof. Wall-mounted exhaust fans are usually used throughout the year.

Running water should be provided, a branch line running to each battery. The supply of water should be controlled by an automatic float or other control device.

To provide for ease in feeding and watering the chickens and removing the manure trays for cleaning, the batteries should be spaced at least 2 ft. 6 in. apart.

Operation Details. The temperature of the air in the brooding section of the starting battery should be about 96°F. for the first 3 days, after which it should be lowered about 3° every 3 days up to about the fourth week. The temperature of the room should be kept at about 60°F. during the day and about 70°F. during the night.

A relative humidity of about 70 per cent should be maintained. The humidifier should be connected with the regular supply of running water

with a float valve arrangement. In the winter months it may be necessary to pour water over the floor to raise the relative humidity. An accurate hygrometer is necessary for measuring relative humidity.

One of the cardinal principles in successful battery-broiler-plant operation is sanitation. Every battery should be thoroughly cleaned and disinfected before chickens are placed in it. The ceiling should be kept clean, and at intervals the walls and floor should be cleaned and thoroughly disinfected. In large broiler plants where the starting, growing, and finishing batteries are in separate rooms, all batteries, walls, and floors should be cleaned and thoroughly disinfected before chickens are transferred from one room to another.

Breast Blisters. A difficulty sometimes encountered in raising broilers in batteries is the occurrence of breast blisters. Breast blisters are usually more prevalent among birds raised in batteries than among birds raised on the range. As a matter of fact, when birds are kept in batteries after attaining a weight of about 2 lb., the proportion of birds affected with breast blisters is likely to be very high. Providing adjustable feed and water troughs and more head room, so that the birds can stand up more, tends to reduce the trouble considerably. Plenty of head room to allow the birds to stand comfortably and the use of ¼-in. flat wire, spaced ⅜ in. apart, are apparently the best corrective measures that can be provided.

COMMERCIAL-BROILER PRODUCTION

The conventional or most popular method of raising broilers is to raise them on the floor, the brooding of the chickens being done with brooders using coal, wood, gas, or oil; electric brooders; or with any of the various continuous hot-water brooding methods described previously.

During recent years the commercial production of broilers and fryers has increased considerably. Broilers are chickens approximately 8 to 12 weeks old weighing not over 2½ lb. each when dressed for market. Fryers are usually from about 13 to 18 weeks old weighing over 2½ but not more than 3½ lb. each when dressed for market. Regardless of the age or weight of the birds at marketing time, however, it has become customary in all parts of the country to refer to the enterprise as commercial-broiler production.

Numbers Reared Together. More chickens per brooder and per 100 sq. ft. of floor space are brooded in units by commercial-broiler producers than are advisable for the farm-poultry raiser who raises pullets for egg production. One reason for this is because the broilers and fryers are all sold at about 12 to 14 weeks of age, and the larger the number brooded per brooder usually the lower the brooding cost per chicken, providing

mortality is not excessive. The number of chickens per brooder varies from about 350 to as high as 750. For the most part, larger sized brooders are used than on general farms. In recent years there has been a tendency to reduce the average number of chickens per brooder because experience has shown that overcrowding retards growth, produces greater variability in size, and increases the spread of disease. On the other hand, under the continuous method of brooding, several thousand chickens are often brooded in one room without partitions of any kind.

FIG. 114. A commercial-broiler house in Delaware. (*A. E. Tomhave.*)

Different kinds of litter are used, including straw, shredded cornstalks, ground corncobs, peat moss, pine needles, shavings, and sand.

Types of Houses Used. Most of the commercial-broiler houses are of simple design. The shed-roof and gable-roof types of house predominate. Most of them are about 20 ft. deep, and their length depends upon the number of chickens to be brooded under one roof. Where continuous brooding is practiced, the houses are up to 50 ft. deep. Many houses are about 80 to 400 ft. long and are divided into pens, each 20 by 20 ft., or 20 by 30 ft., a brooder being used in each pen. In other houses there are no partitions, although a few partitions are advisable to break drafts and avoid chicks piling up in corners.

Dirt floors predominate, although concrete floors are much more sanitary and are used to some extent.

The fronts of the houses are relatively open, windows or burlap being

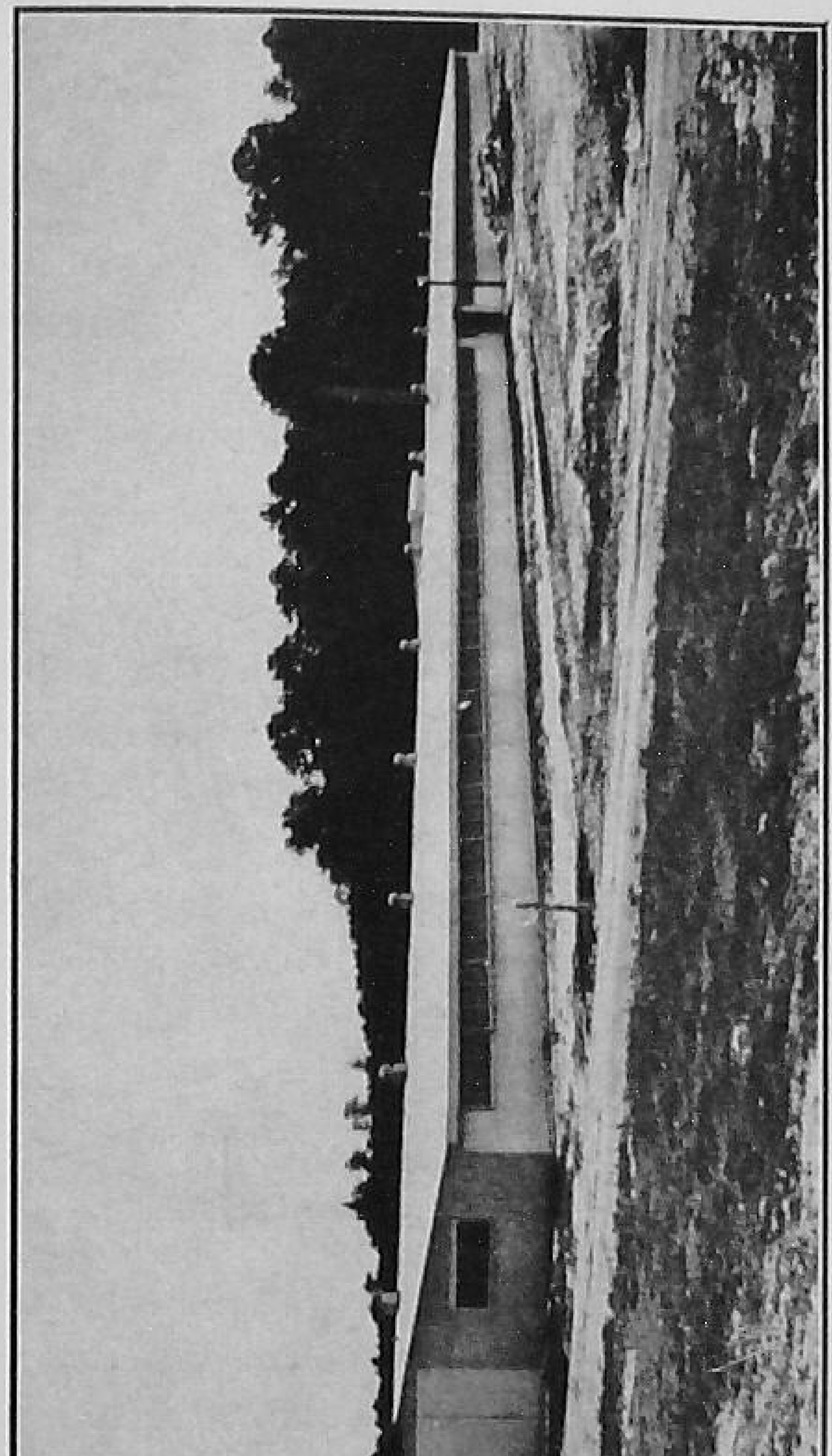

FIG. 115. The W. Lane and R. H. Lagarde broiler house in Maryland, 48 by 312 ft., centrally heated. The house has a capacity of 20,000 birds and is equipped with a duct-type heating system. Steam is piped to heat exchangers which blow warm air into ducts, which carry the warm air lengthwise through the building. This system makes it possible to cool the house in hot weather. (*Poultry Tribune.*)

used to cover the openings in cold weather or in case of driving rains. Most of the houses have windows in the rear to provide for adequate ventilation in warm weather. Occasionally during an excessive heat wave an operator may lose several thousand birds from heat prostration, especially if the house is poorly ventilated and is overcrowded with birds almost ready for market.

In most cases, the chickens are allowed access to the ground in front of the house, and in other cases each pen is provided with a yard of limited size. Although green crops are usually grown in front of the house, the yard is usually bare shortly after the chickens are allowed outside.

Number of Lots per Year. Broilers are produced commercially every month in the year. In the early years of the commercial-broiler enterprise, there was a marked tendency toward seasonality of production, the volume of production being greatest from April to July and the next greatest volume being during December and January. In recent years, however, the tendency toward seasonality of production has largely disappeared. The establishment of dressing plants in broiler-producing areas has been largely responsible for more uniform production throughout the year. This is natural because the dressing plants need a relatively uniform supply in order to operate most efficiently. Since about 13 or more weeks are usually required to grow broilers of the most suitable size for marketing, three lots per year can be turned out by each producer. Some broiler producers with very fast-growing strains and who sell their broilers at an average weight of about 3 lb. might be able to turn out four lots in 1 year.

CAPON PRODUCTION

In many of the larger cities there are good markets for large roasting chickens. The largest size for roasting is obtained when the cockerels of certain breeds are castrated. A castrated chicken is known as a "capon" and since capons attain their maximum size when about 8 to 10 months of age, they are ready for market after the Christmas holidays, when other forms of fresh-killed young poultry, except broilers, are scarce. Capons retain the tenderness of the meat characteristic of young cockerels. Some poultrymen hatch chicks in December and January so that their capons are ready for the Thanksgiving markets. A special set of instruments is necessary for caponizing, and several different makes are made by manufacturers.

Breeds to Caponize. The largest capons are obtained from such breeds as the Jersey Black Giant, Langshan, and Brahma. These breeds, however, are slow to mature and will hardly develop in time for the holiday season unless hatched early. Plymouth Rocks, Rhode

Island Reds, New Hampshires, and Orpingtons make excellent capons and can be brought to prime condition in 7 to 10 months.

Age to Caponize. Healthy, vigorous cockerels should be selected, and the operation should be performed before there is much sign of comb development, birds from 1½ to 2½ lb. in weight or from 8 to 12 weeks of age being most desirable. The cockerels should be placed in clean crates without litter and kept in a comfortable place without water or feed for a period of 12 to 24 hr. This fasting period is very important, for the operation is most easily performed on properly fasted birds, and there is usually much less bleeding.

How to Caponize. Caponizing should be done on a bright, sunny day. Set up a barrel or two egg cases as a table on which to work, or construct a table if large numbers of cockerels are to be caponized. A crate con-

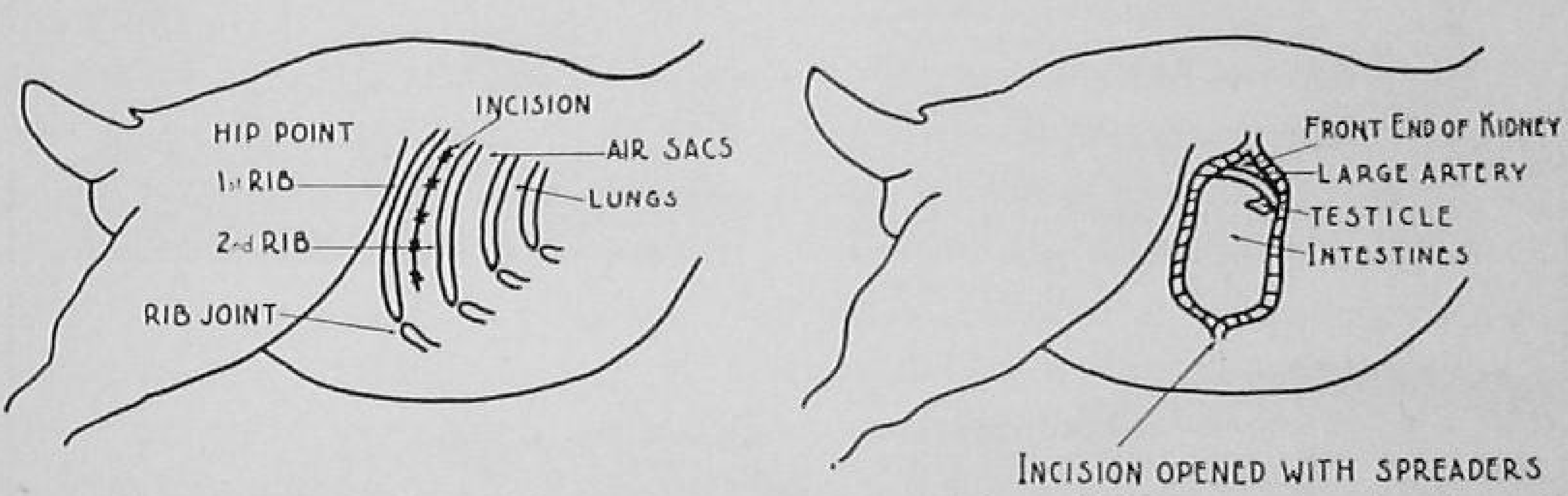

FIG. 116. Left, showing the place to make the incision. Right, showing location of testicle. (*H. H. Kauffman and L. F. Leuschner, Pa. State Coll. Ext. Service.*)

taining the cockerels should be close at hand, and another empty crate should be provided to receive the capons after the operation.

The cockerel should be fastened firmly to the caponizing board or table by means of straps. One strap should be placed around the wings close to the body, the end drawn through the ring, and the strap fastened to the board by means of some slots and a screw eye. The other strap should be placed around the legs above the hock joint and, after the bird is in position, should be fastened in the suitable slot. In securing the bird to the board, the left side should be next to the board with the right side of the bird facing the operator. Since the incision is made between the last two ribs of the bird, a few feathers should be plucked from this region, thus exposing these ribs. This area should be dampened, and the surrounding feathers should be soaked thoroughly so that they are held back out of the operator's way and do not obstruct his view.

In making the incision, the knife should be held firmly between the thumb and forefinger, only about ¼ in. of the blade being exposed. Held in this manner, it is hardly possible to cut so deeply that the intestines are injured. With the forefinger of the left hand, locate the last

two ribs which lie just in front of the hip joint. Draw the skin back toward the hip and place the knife between the ribs approximately ½ to ¾ in. below the backbone. An incision about 1 in. long is made by drawing the knife toward the operator, being careful to follow the curve of the ribs. The spreader should then be inserted, and the incision opened as far as possible without tearing the flesh. With the tearing hook, tear the thin membranes that cover the intestines, but carefully

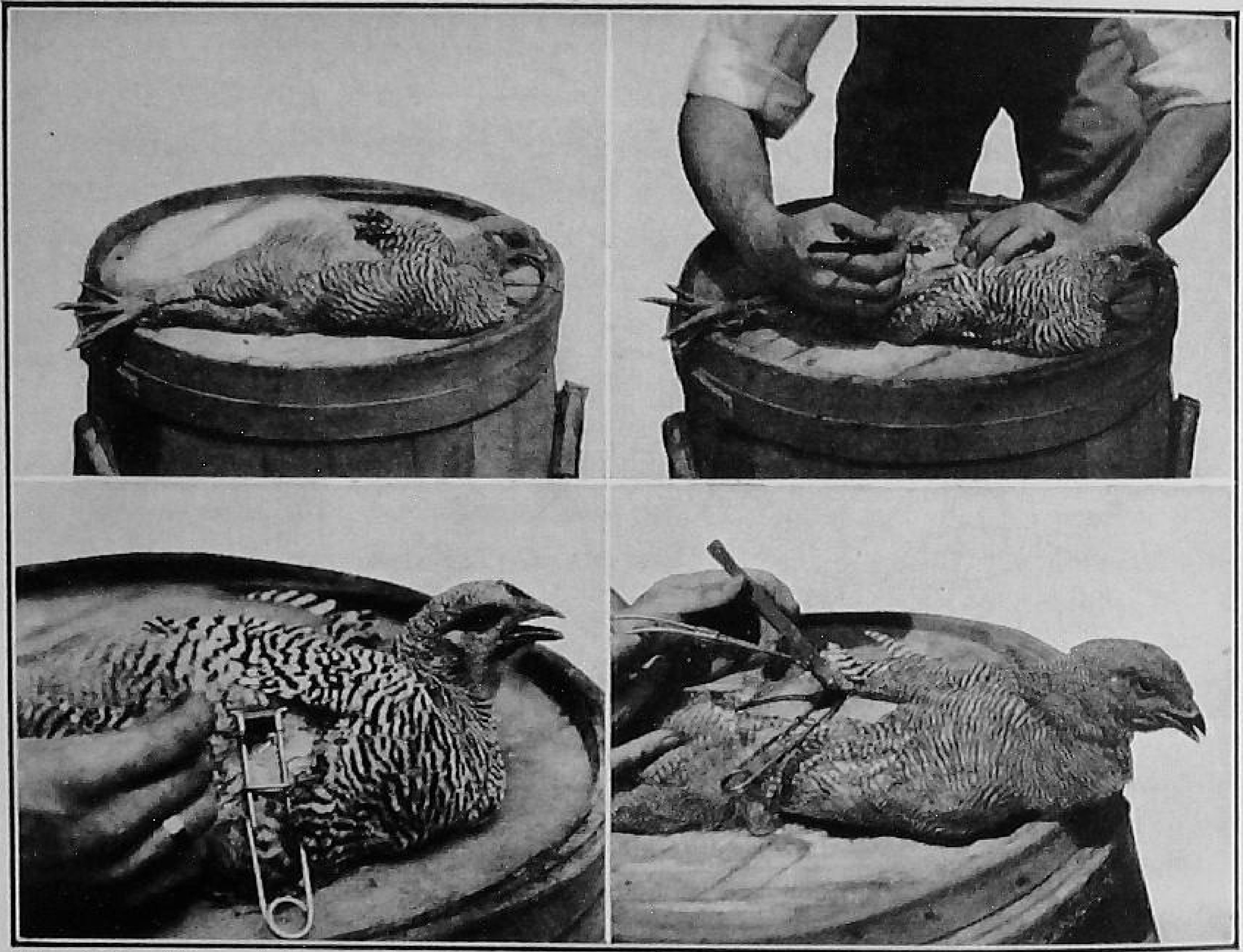

FIG. 117. Upper left, a cockerel in position for caponizing, with feathers removed for making the incision. Upper right, making the incision. Lower left, the spreaders inserted and a probe inserted to locate the testes. Lower right, removing the testes. (*U.S. Dept. Agr.*)

avoid hooking the intestines. The upper testicle can then be observed lying just below the front end of the kidney and close to the backbone.

In birds of proper size, the testicle will be about the size of a grain of wheat and usually deep yellow, although at times the color may be gray or even black. The lower organ lies just underneath the upper one and may be seen by raising the upper one with the probe. A large artery will be observed running between the two; should this be punctured during the removal of the organs, death will result. With the jaws of the removers slightly open, reach underneath the lower testicle and gently move the instrument upward, allowing the organ to slip between the open jaws. Being sure that the entire organ is within the remover and that

no blood vessels have been grasped, slowly pull the instrument out of the body cavity with a twisting motion until the organ is severed from the body. Next, remove the upper testicle in a similar manner.

Should difficulty be encountered in attempting to remove both organs from one side, the upper one should be removed, and the bird turned over and operated on from the left side. It is essential that the organs be removed intact, for if the wall of the testicle is ruptured and a portion allowed to remain in the body cavity, a "slip" will result.

Some birds may become troubled with wind puffs, which result from air escaping from within the body cavity before the incision is healed and becoming trapped beneath the skin. These wind puffs should be punctured with a sharp instrument.

The fact must be appreciated, of course, that capons do not necessarily grow faster than cockerels, so that in order to gain any particular advantage over the production of roasters, capons must be kept for a longer time, or a higher price should be secured. The impetus given to the production of broilers has resulted in a decreased demand for capons.

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CHAPTER 8

HOUSING AND YARDING PRINCIPLES AND PRACTICE

With birds of good breeding, fed well-balanced diets, and properly managed, the measures of good housing are the comfort of the birds and the number of eggs produced. The laying house should provide the essentials of comfort and sanitation necessary for sustained egg production in the climate where the house is located.

Although it has been demonstrated repeatedly that good egg production is possible under a wide variety of environmental conditions, it has also been demonstrated that sudden extreme changes in temperature within the laying house are very apt to affect egg production seriously. Extremely high temperatures in the laying house not only result in decreased egg production but may cause excessive mortality due to heat prostration. Extremely low temperatures inside the laying house, besides decreasing egg production, introduce the serious problem of providing adequate ventilation to avoid excessive dampness, especially when the cold winter atmosphere has a high relative humidity.

FUNCTIONAL REQUIREMENTS OF HOUSING

In all sections of the United States, the layers must be protected from excessive summer heat and rain. In the northern sections of the country, they must be protected in winter from rain, snow, cold winds, excessively low temperatures, and sudden severe changes in temperature.

In those sections where mild winters prevail, the problem of providing comfort from excessively high temperatures during the summer months is relatively more important than protection from very low temperatures during the winter months. Florida and sections of the country along the Gulf of Mexico have the highest winter temperatures, and Arizona and adjoining regions have the lowest relative humidity and the most sunshine.

In northern sections, the problem of providing comfort during the winter months is much more important than during the summer months. This is especially true in the northern parts of Minnesota, Wisconsin, and North Dakota, where the average temperature is below 10°F. in January, the average relative humidity above 80 per cent, and the average winter sunshine less than 5 hr. per day. Somewhat milder winter tem-

peratures prevail in certain parts of the Pacific Northwest and in the central Great Lakes area; but the average relative humidity during January is above 80 per cent, and there are less than 3 hr. of winter sunshine per day.

Within a given area of the country, altitude is a factor because for each 400-ft. rise above the elevation of the area the average temperature is about 1°F. lower.

These variations in climatic conditions determine to a considerable extent the kind of house to build in an attempt to provide year-round comfort for the layers.

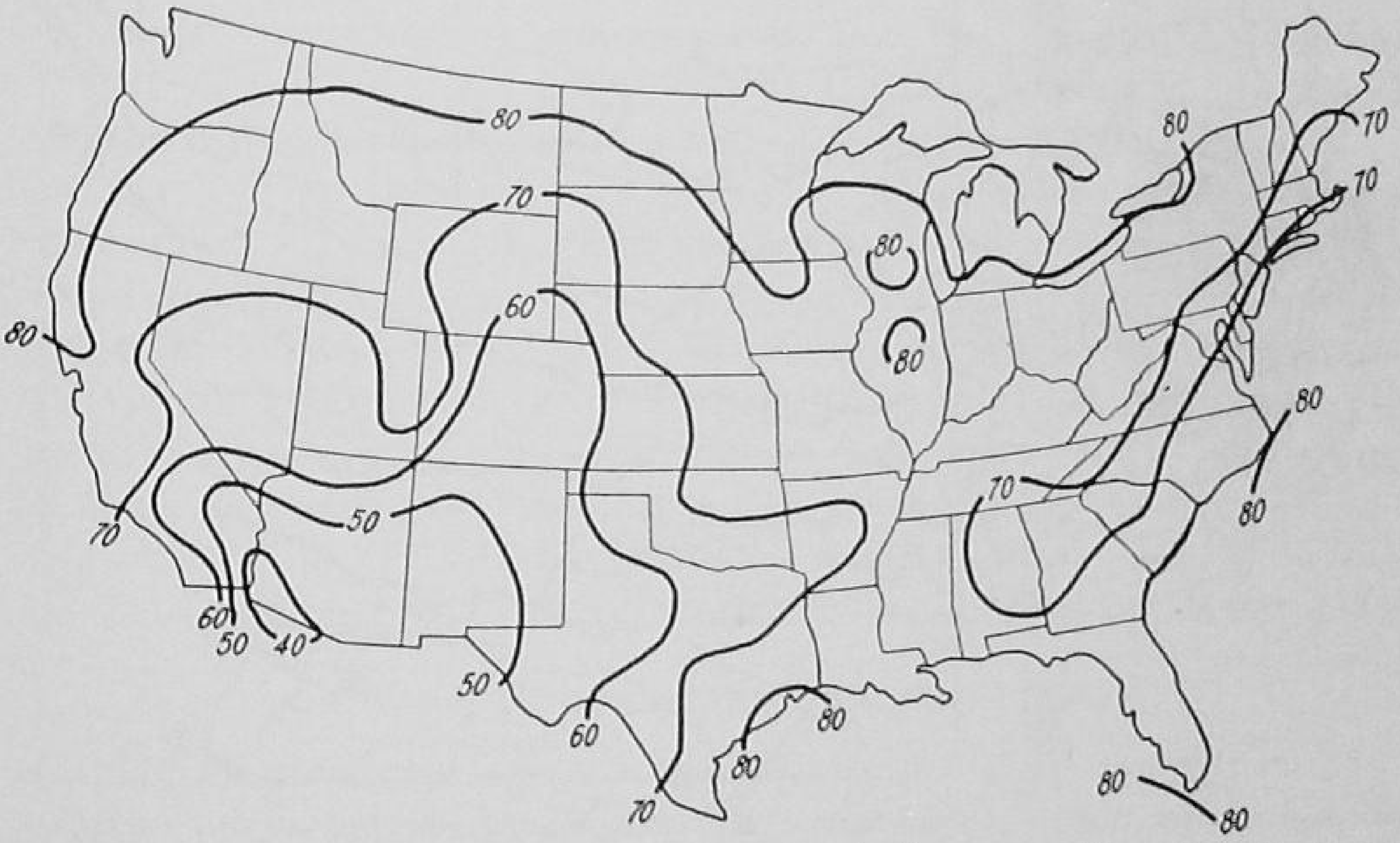


Fig. 118. Percentage of average relative humidity in January. (*W. Ashby, T. A. H. Miller, G. L. Edick, and A. R. Lee, U.S. Dept. Agr.*)

The Temperature Problem. Egg production is normally at its highest level in the spring of the year when the temperature is about 50 to 60°F. outdoors. When the temperature drops to about 10°F. in cold regions of the country or below 20°F. in milder regions, combs and wattles are liable to freeze and egg production usually decreases.

The body temperature of the hen is about 107.5°F. She is a rapid breather, and her pulse and metabolic rates are high. She has no sweat glands, so that her body temperature is regulated by the evaporation of moisture from her lungs and skin.

Since the hen's body temperature is considerably higher than the temperature in the laying house, she loses heat constantly. This lost heat must be replaced regularly or her body temperature will fall. In winter, heat loss from the hen's body is naturally greater than in summer.

Therefore, in order to maintain a relatively constant body temperature, heat production is greater in winter than in summer. Cold walls and floors and strong drafts in the house increase the loss of body heat. Cold air with high relative humidity absorbs more heat from the laying pen than dry air. Thus the hen is required to produce more body heat in order to maintain the normal body temperature. Conversely, heat loss from the hen's body is decreased by increased feed consumption, greater physical activity, higher air temperatures, and relatively high wall and floor temperatures.

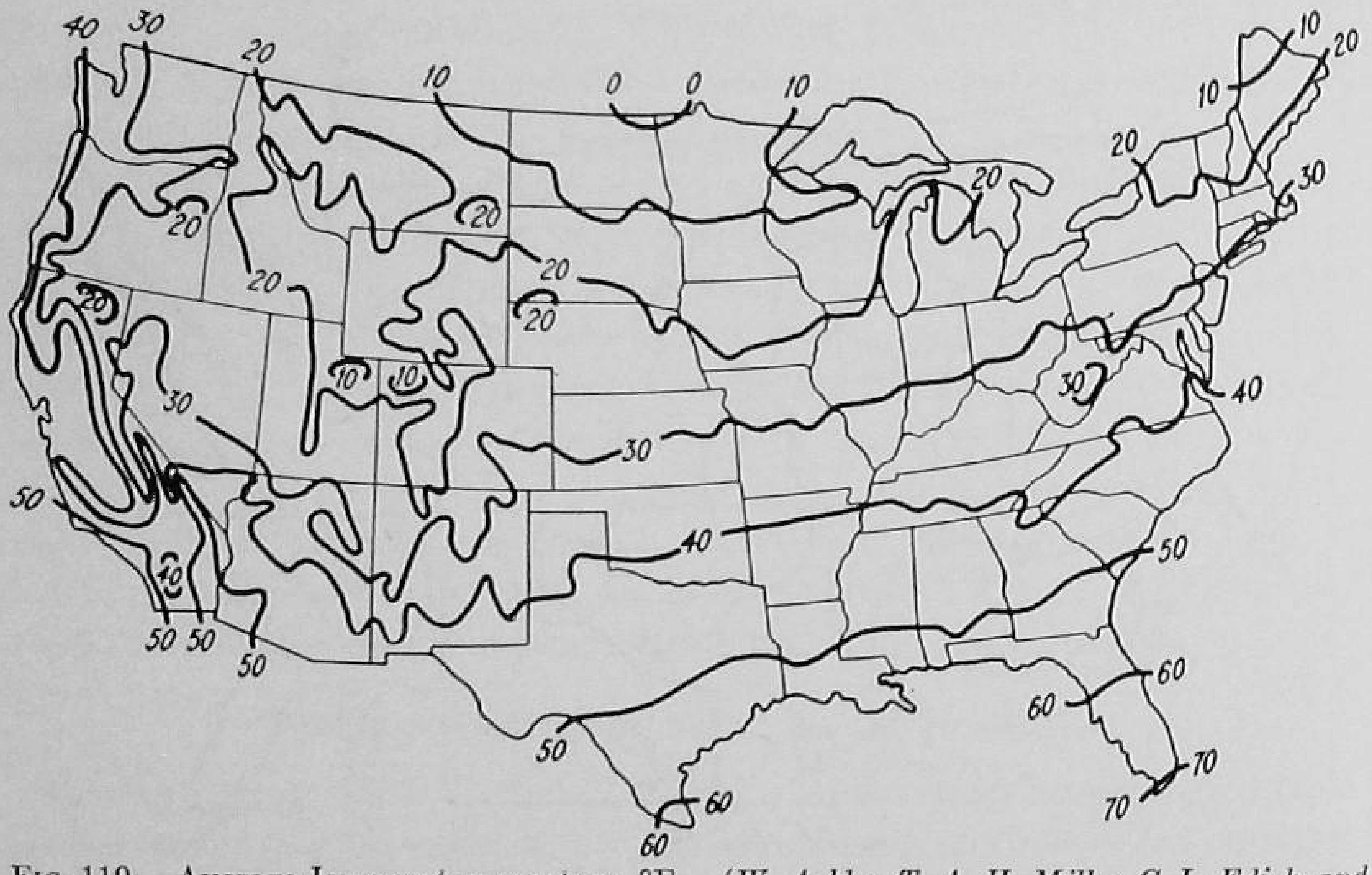


Fig. 119. Average January temperature, °F. (*W. Ashby, T. A. H. Miller, G. L. Edick, and A. R. Lee, U.S. Dept. Agr.*)

The amount of heat lost from the hen's body is influenced by the amount of water lost by vaporization, a process requiring heat. Increased heat production naturally increases the amount of heat lost as heat of vaporization. Heat loss due to vaporization is much greater at high temperatures than at low temperatures. Apparently, about 85°F. is the maximum temperature at which laying hens can dispose of excess heat and still lay and function normally. On the other hand, about 15°F. is the minimum temperature to which a hen on full feed and active during the day can be subjected before she is compelled to draw on food nutrients in order to maintain body temperature, but the laying-house temperature during the day should be kept above 32°F. For hens roosting at night, the minimum temperature is about 40°F. before food nutrients are used to maintain body temperature.

Laying hens are able to furnish only a part of the heat necessary to maintain a comfortable temperature within the house during cold weather. A hen weighing 4 lb. produces about 40 B.t.u. (British thermal units) of heat per hr., and a hen weighing 6 lb. produces about 52 B.t.u. per hr. This is not sufficient to keep an uninsulated house at a comfortable temperature in cold weather.

The sun is an important source of heat in areas having considerable winter sunshine. In a laying house with the floor and foundation in direct contact with the ground, the earth helps to keep the house warm

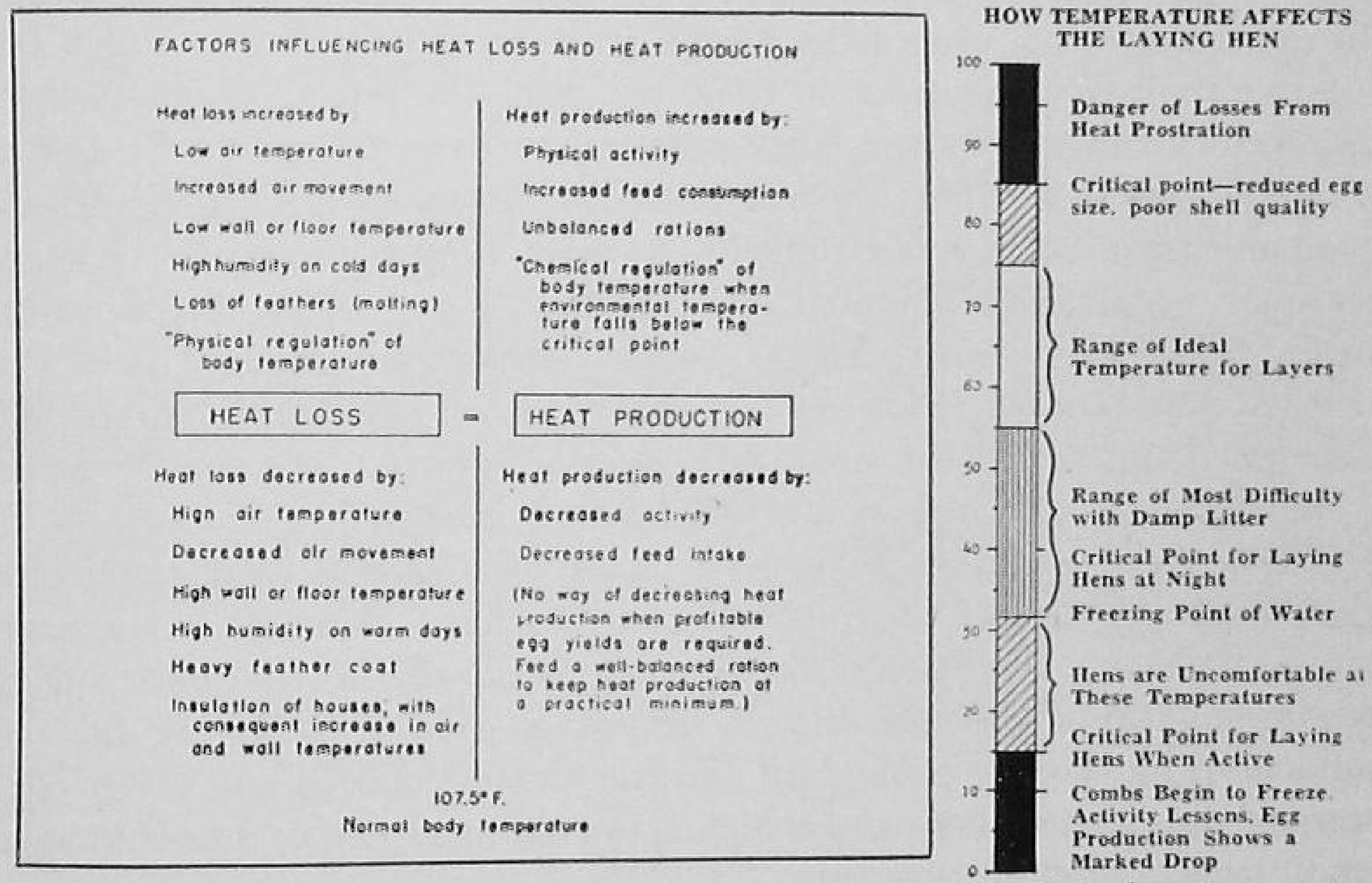


FIG. 120. Left, factors influencing heat loss and heat production. Right, how temperature affects the laying hen. (*L. E. Card, Canadian Poultry Review*, 1947.)

whenever the temperature of the air is lower than the temperature of the ground. During cold spells, ground heat helps to prevent sudden drops in temperature within the laying house. However, when there are less than 5 hr. of sunshine daily and the average outside temperature is below 10°F., the heat given off by the hens and the heat from the sun and the earth are not sufficient to maintain comfortable temperatures unless the house is well insulated.

In most sections of the United States, the insulation of the roof of the laying house is desirable. During hot summer months, roof insulation tends to keep the house cooler. During cold winter months, especially in the northern sections of the country, roof insulation is necessary to conserve heat; in some areas, insulated walls are also desirable. Since laying hens are not too well adapted to sudden changes in the weather, a

sufficient amount of insulation is necessary to help keep sudden changes in outside temperatures from quickly affecting the inside temperature.

Apparently, a range in temperature of from about 55 to about 75°F. in the laying house is the most suitable temperature from the standpoint of providing comfort for the birds and economical egg production.

The Moisture Problem. The water of vaporization given off by laying hens adds considerable moisture to the atmosphere of the laying house. This is important when hens are confined during the winter months. It is estimated that, at 50°F., 100 4-lb. hens exhale about 12 lb. of water daily. At higher temperatures, the rate of water elimination is increased. In one experiment, when hens were kept in an atmosphere in which the relative humidity was from 50 to 60 per cent, the rate of elimination of respiratory water remained fairly constant between 65 and 75°F., but at temperatures above 75°F. the rate tended to increase, very rapidly after a temperature of 85°F. was attained. At 90°F. approximately three times as much water was eliminated as at 80°F. At prevailing temperatures in the majority of poultry houses during the winter months, it is safe to assume that at least 350 lb. of respiratory water are eliminated per 100 hens per month. At the same rate, over 1,000 lb. of respiratory water would be eliminated by a pen of 300 hens per month.

The amount of water eliminated in the droppings is more important than is the amount of respiratory water eliminated from the standpoint of maintaining a condition of relative dryness in the laying house during winter months. The quantity of droppings voided by laying hens is influenced by the size of the bird and the amount of feed and water consumed. Large hens laying at a high rate void much larger amounts than small hens laying at a low rate.

Only approximate estimates of water voided are available, but they are sufficient to indicate the large amounts of water voided by the average flock. Hens weighing about 5 lb. and laying well will probably void over 150 lb. of droppings per bird per year. Strictly fresh droppings contain approximately 85 per cent moisture, the amount of water voided in the droppings being about 125 lb. per hen per year. Thus, during 6 months of confinement, a pen of 100 hens of good size would void in the house over 1,000 lb. of water per month, and a pen of 300 hens would void about 1.5 tons per month. Approximately between 2 and 3 per cent of the water supply provided for the birds is spilled on the litter, if there is no underground drainway, thus adding to the litter-moisture problem.

The total amount of respiratory water and voided water in the droppings per month is about 1,350 lb. per pen of 100 birds, and per pen of 300 birds it would be about 2 tons.

The addition of such large amounts of water to the house atmosphere

and litter requires some degree of ventilation of the laying house to avoid condensation of moisture on the walls and ceiling in cold weather and to facilitate evaporation of moisture from the litter.

The Ventilation Problem. In cold weather, ventilation is not only necessary to remove some of the surplus moisture that accumulates in the laying house but also to remove foul air, prevent sudden changes of temperature within the laying house, and eliminate drafts of cold air.

The change of air required to remove moisture varies with the temperature and relative humidity outside and inside of the laying house. When the outside temperature is 10°F. and the relative humidity is 80 per cent but inside the laying house the temperature is 15°F. and the relative

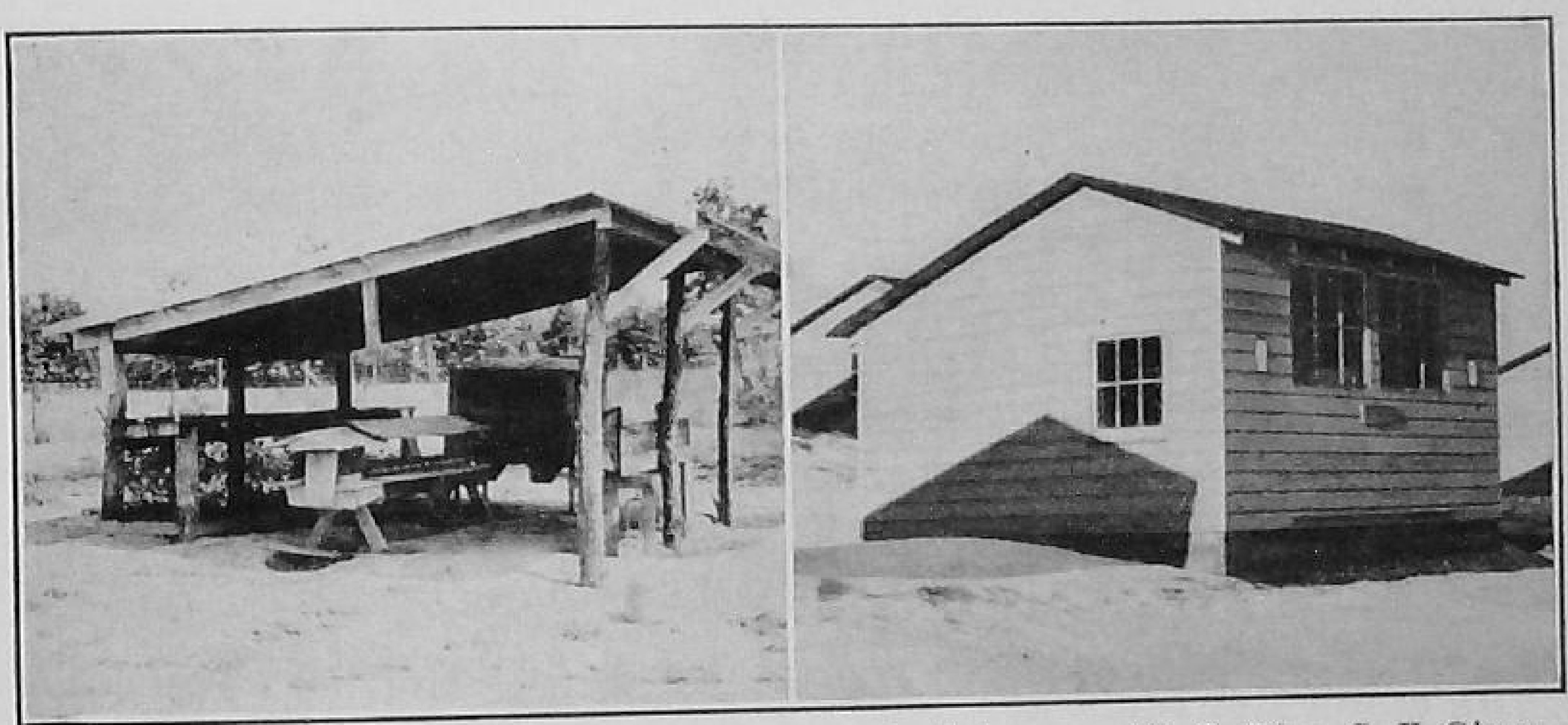


FIG. 121. Left, a simple shed-roof type of house in Alabama. (*D. F. King, S. E. Gissendanner, and R. C. Christopher, Ala. Exp. Sta.*) Right, a gable-roof type of laying house suitable for northern sections of the United States.

humidity is 80 per cent, about 350 cu. ft. of air change per hen per hour are needed to remove 0.25 lb. of moisture per hen per day. On the other hand, when the outside temperature is 10°F. and the relative humidity is 80 per cent but inside the laying house the temperature is 35°F. and the relative humidity is 75 per cent, about 60 cu. ft. of air change per hen per hour are needed.

Air at 45°F. carries about twice as much moisture as air at 25°F. Since excess moisture in the laying house must be eliminated by air conducted to the outside by the ventilating system, warmer temperatures reduce the amount of ventilation needed and also reduce the amount of heat loss through the ventilated air. When the outside temperature is very cold, in a well-insulated house the temperature changes will be relatively slow and the birds will have time to adjust themselves gradually to the changing temperature.

The system of ventilation installed in the laying house should provide

uniform movement of air through the house without drafts, especially in case of strong winds or sudden changes in outside temperature. It is particularly important to avoid drafts over the birds while roosting. In some sections of the country, electric fans are used to keep the laying house ventilated especially during cold weather.

When birds are confined to the house in cold weather, unless the air is changed regularly it loses much of its oxygen, contains an excess of carbon dioxide, and also contains relatively large amounts of ammonia given off by the droppings. Most of these objectionable conditions can be controlled to a considerable extent by proper ventilation.

LOCATION OF THE LAYING HOUSE

In the case of most farmers and all commercial-egg producers, the laying flock provides the major share of the total poultry income obtained each year. For this reason, careful consideration should be given to factors that affect returns secured in egg production.

Exposure. Depending upon prevailing winds in a given locality, the laying house should face south or southeast. This permits the greatest amount of sunshine to enter the house, an important factor during the winter months. Land sloping gently southward away from the house is desirable, especially in the case of farm flocks that are often allowed outdoors early in the spring, because the soil is warmer than soil on the level or on other slopes.

Air and Water Drainage. Sandy or gravelly loam is the best kind of a soil on which to locate a laying house because porous soil offers good water drainage and thus tends to keep warmer than heavier types of soil. Cold, damp air tends to settle in low places, a house in a depression being more difficult to ventilate properly.

The choice of type of soil is restricted, of course, to the type on the farm or poultry plant. Whatever type of soil is available, air and water drainage are both facilitated by locating the house on a southerly slope if such is available. Sloping land tends to drain away filth and disease organisms and dries more quickly than level land. The birds usually keep healthier, and fewer dirty eggs are produced, when the birds are allowed outdoors.

Where level land only is available for the house site, poor natural drainage can be improved by laying tile around all sides of the foundation to carry water away from the building.

Protection against Winds. Strong winds blowing against the laying house tend to increase the loss of heat from the house and are liable to cause drafts. If it is necessary to locate the house in an exposed place, a planting of evergreens a reasonable distance from the house would serve

as a windbreak. This would tend to prevent sudden changes in temperature inside the house and thus keep the birds more comfortable.

Shade in Summer. Birds that are allowed outdoors during the hot summer months derive comfort from shade trees. They tend to protect

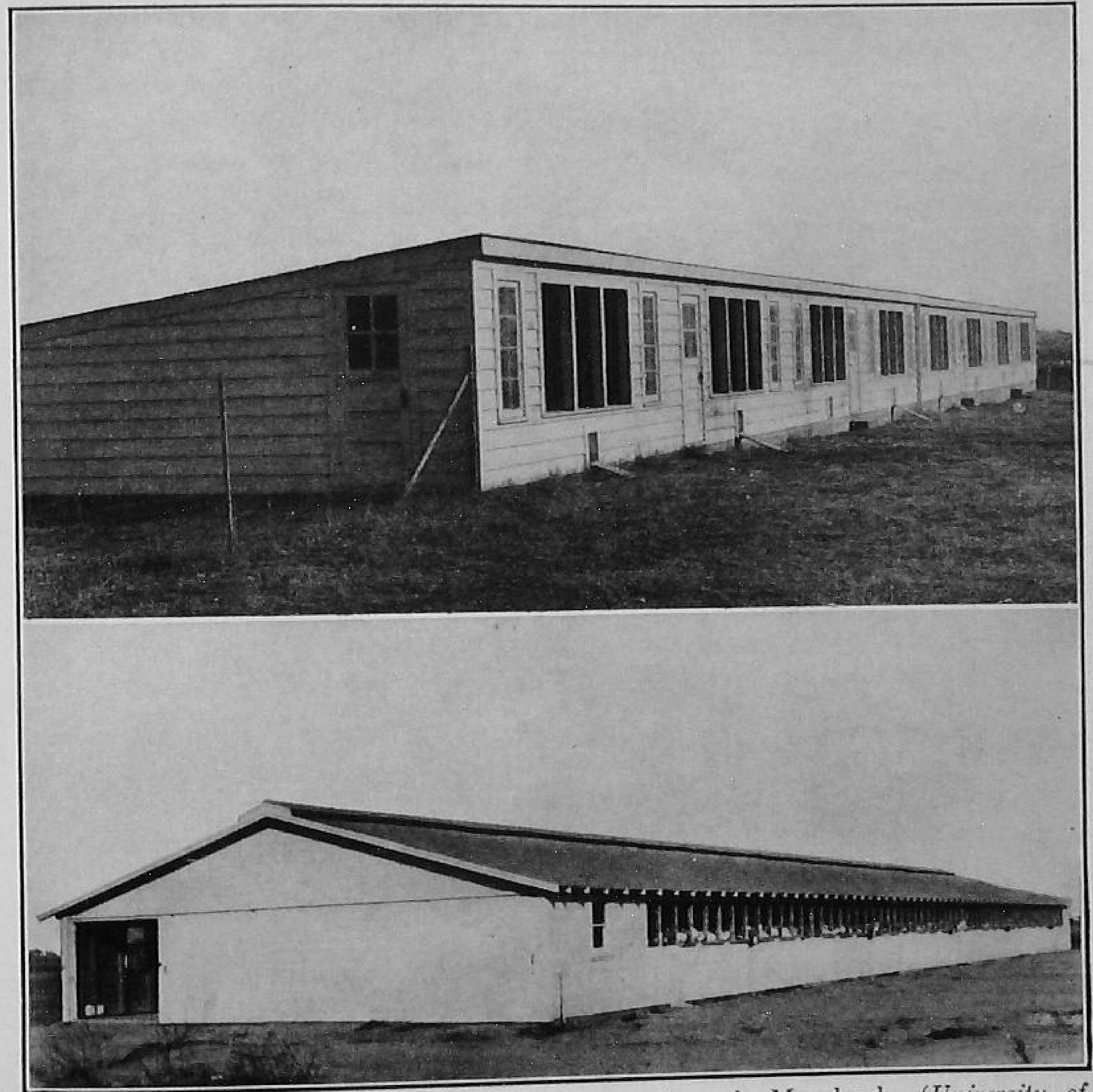


Fig. 122. Top, a 20- by 160-ft. shed-roof laying house in Maryland. (*University of Maryland.*) Bottom, Dan Bakker's 36- by 150-ft. laying house in California; it contains 10 wire-floor pens to help keep eggs clean. (*R. C. Hartman in Pacific Poultryman.*)

the birds against the possibility of heat prostration. At the same time, the trees should not be so dense as to prevent sunlight to reach the soil or it soon becomes contaminated. An orchard, where the soil is cultivated regularly, is a desirable place for layers.

Relation to Other Buildings. The laying house should be reasonably convenient to the home for the simple reason that if farther away than is necessary, the attendant over a period of a few years will walk many need-

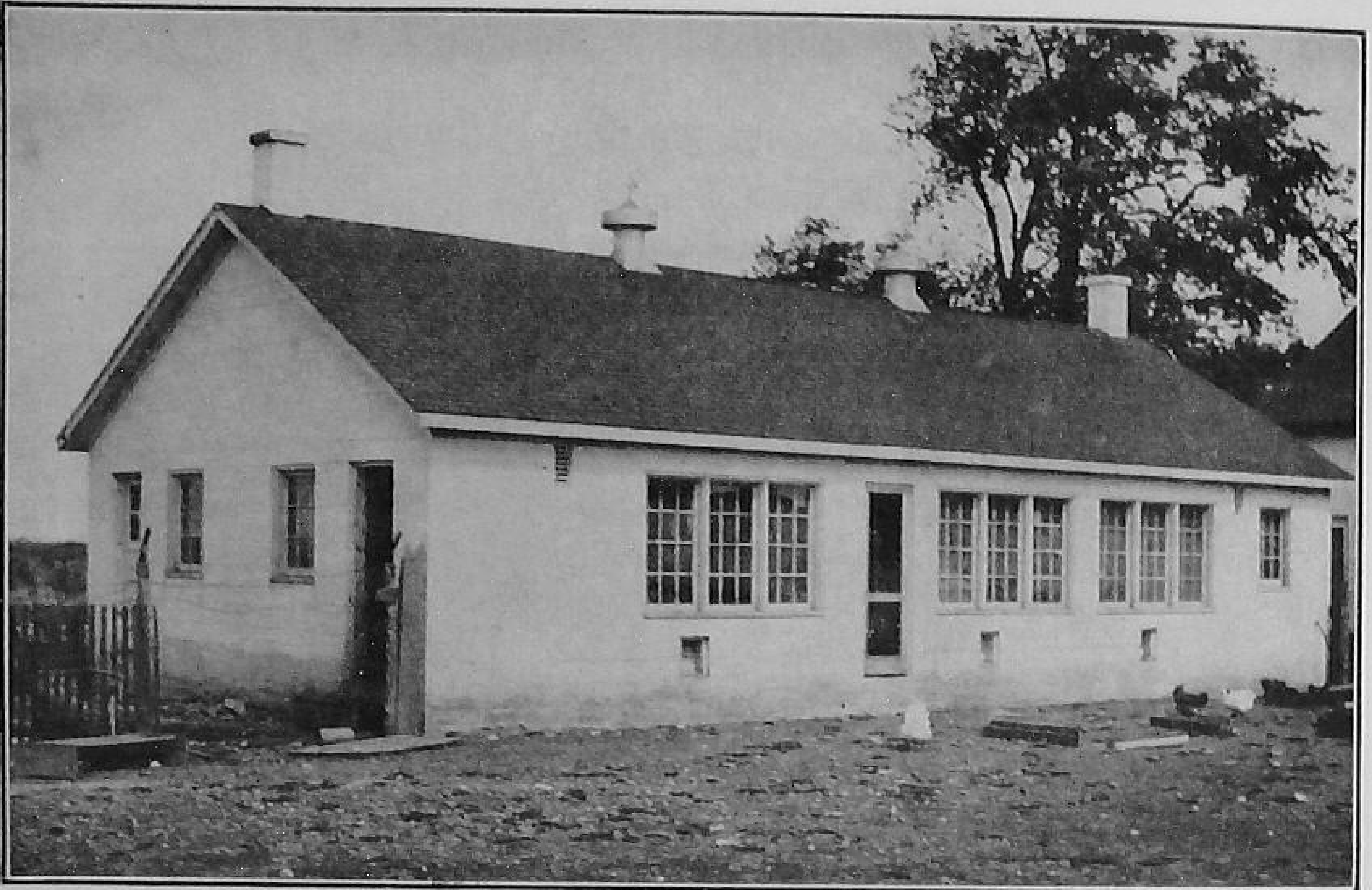


Fig. 123. Top, a concrete poultry house. (*Portland Cement Company.*) Bottom, the walls of this Minnesota straw-loft laying house are made of two thicknesses of 4-in. clay tile laid with a 2-in. space between them, the walls being 10 in. thick. (*Poultry Tribune.*)

less miles. On the other hand, the laying house should not be so near the dwelling that the birds when allowed outdoors, if not kept in yards, will damage the garden and make a nuisance of themselves around the house.

Where to locate the laying house in relation to other buildings should be determined to some extent by the possibility of adding to the laying house or building additional laying houses. Also, from the standpoint of fire risk, laying houses should be at least 100 ft. from other structures.

From the standpoint of the layout of all farm buildings, the laying house or houses should be located in relation to the dwelling and other farm buildings so that the chore route in tending the laying flock ensures proper management in the minimum amount of time.

ESSENTIALS OF A GOOD HOUSE

Good housing conditions and laborsaving conveniences are desirable in all laying houses, small and large. The essentials of a good house include: (1) proper type of house; (2) adequate floor space; (3) provision for adequate summer and winter ventilation; (4) availability of sunlight; (5) proper distribution of light within the house; (6) well-arranged interior; (7) protection from rats; (8) durability.

Types of Houses. Laying houses vary with respect to their width, height at front and rear, relative area of the front left open or provided with windows, style of roof, the amount of insulation provided, ventilation systems used, and in other ways. On most farms one-story houses are used, but on commercial-egg-producing plants one-story or multistory houses are used.

The size of the house is determined by the size of the laying flock maintained and the floor space allotted per bird. A multistory house costs less per bird to build than a one-story house because each requires one roof and one foundation regardless of the number of floors in the house. Unless about 1,500 or more layers are kept, however, a one-story house is to be preferred.

Many poultry houses on farms are too small and not wide enough to keep the birds comfortable in cold weather and provide for properly controlled ventilation. Rarely should a house be less than 20 ft. wide, and in many cases a width of from 24 to 36 ft. gives better results, especially during the winter months.

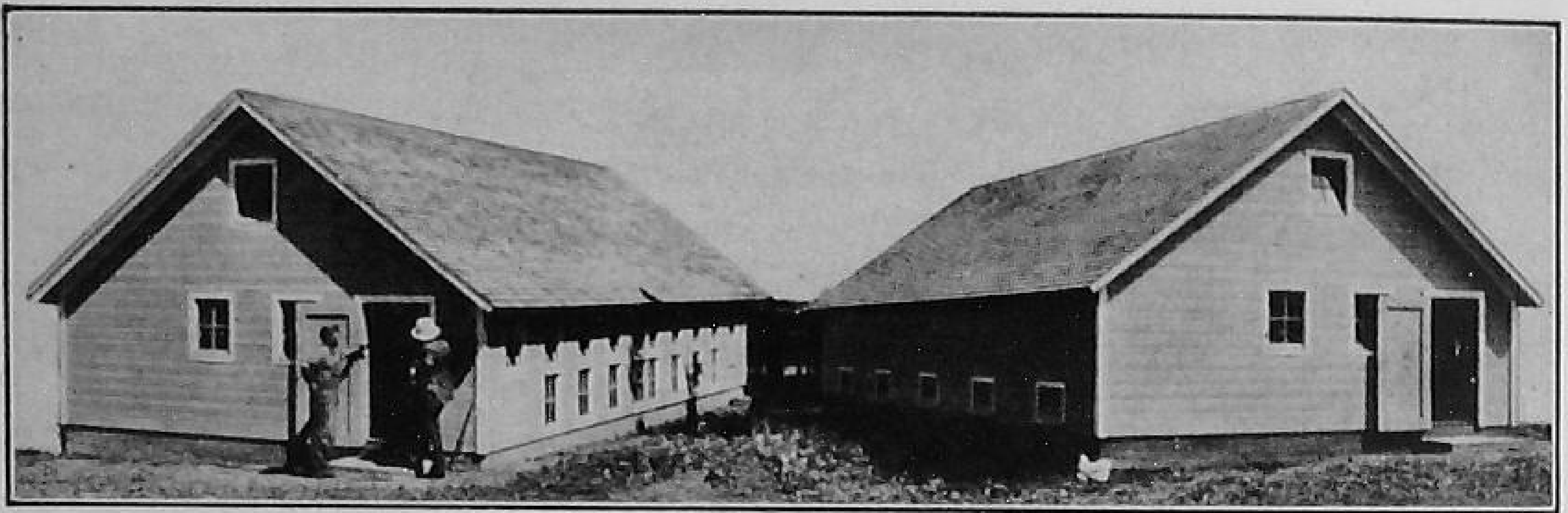
The height of the front and rear of the house is influenced by the style of the roof. In the case of a shed-roof house the front is higher than the rear, whereas in the gable-roof and combination-roof types of house the front and rear are of the same height. The semimonitor type of house is objectionable because it tends to be drafty.

At the front of the droppings board, if one is used, a height of about 6 ft. to the ceiling or lower side of the rafters is necessary for cleaning the droppings board. The ceiling should be at least 7 ft. high if deep litter is maintained or if feed and litter carriers are used. In southern sections of the country, the ceiling is usually 1 to 2 ft. higher than in northern sections.

Floor Space per Bird. The floor space required per bird depends to some extent upon the size of the laying house or the size of the pens in the

house. The smaller the house or pen, the more the floor space required per bird.

Leghorns require slightly less floor space per bird than general purpose layers.



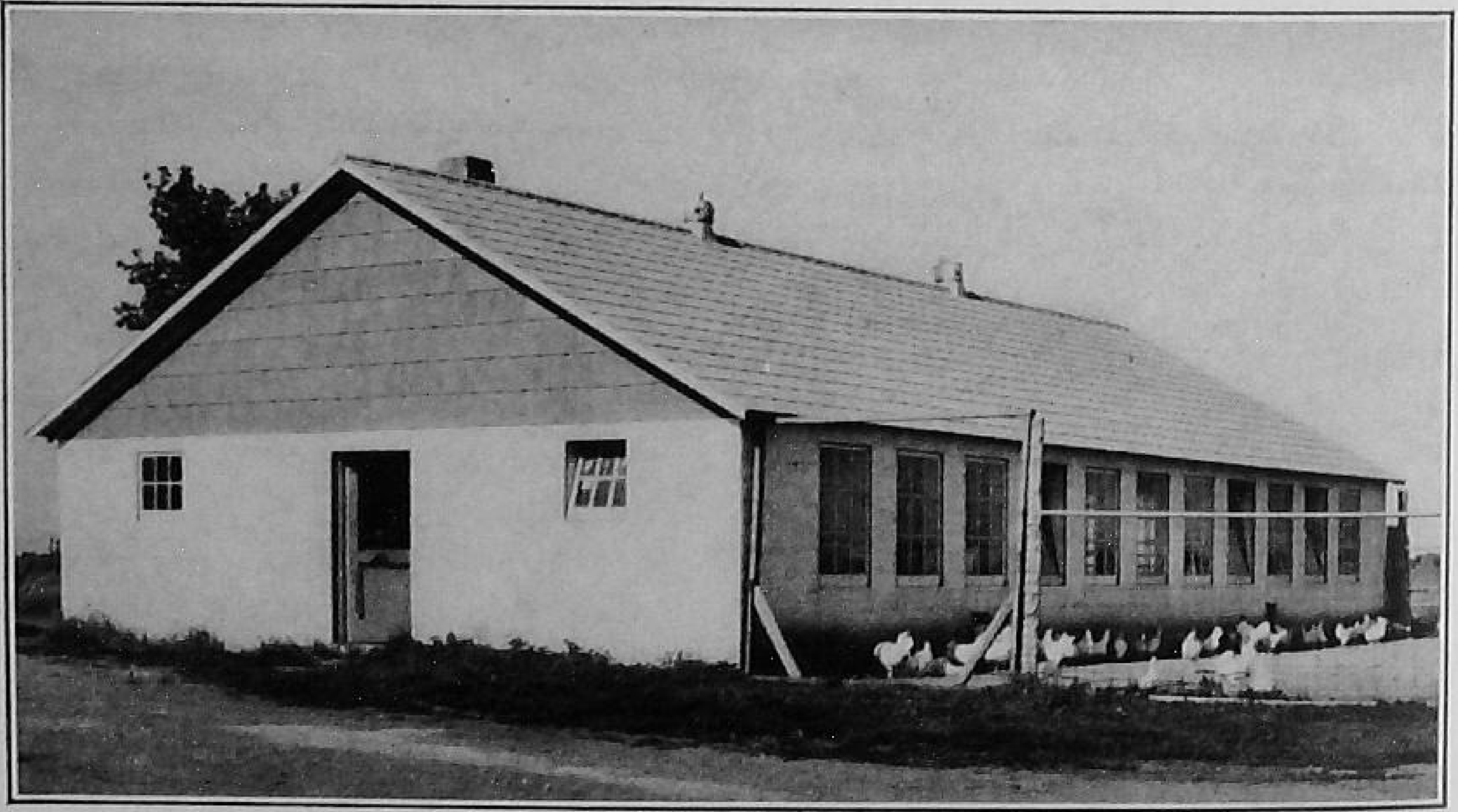


FIG. 124. Top, a 20- by 40-ft. straw-loft laying house, showing front and rear views. Note the arrangement of windows in front, ends, and rear. (*Hoard's Dairyman.*) Bottom, a masonry straw-loft laying house in Illinois, the walls of which are made of 8-in. lightweight concrete blocks. The roof is made of asbestos shingles, and the walls are painted with a white portland-cement paint. (*Poultry Tribune.*)

In those sections of the country where the birds are allowed outdoors the year round, about one-half as much floor space per bird is needed as when birds are confined to the house throughout the year.

Overcrowding the house or pen presents several dangers. There is more danger from feather picking, cannibalism, and the spread of disease. Egg production per bird is apt to be lower than when adequate floor space per bird is provided. On the other hand, when more floor space per bird is provided than is needed, the cost of housing is greater than necessary,

and in northern sections of the country it is more difficult to provide comfortable conditions within the house during cold weather.

Less labor per bird is required in caring for large pens of layers than small pens of layers, but there is a limit concerning the number of birds per pen for satisfactory results in egg production.

Table 32 gives the floor space required per bird according to size of breed and number of hens per pen.

TABLE 32. FLOOR SPACE REQUIRED FOR LAYERS OF SMALL AND LARGE BREEDS (W. Ashby, T. A. H. Miller, G. L. Edick, and A. R. Lee, U.S. Dept. Agr., 1945)

Hens in pen	25	100	200	400
Floor space per hen (Leghorns), sq. ft.	4	3½	3	2¾
Floor space per hen (general-purpose), sq. ft.	4½	4	3½	3¼

For best results with a small flock, the depth of the house should be greater than the length. For larger flocks, a popular size of pen is 20 by 20 ft. for about 115 Leghorns or 100 general-purpose layers. Another popular pen size is 24 by 24 ft. for about 200 Leghorns or about 165 general-purpose layers. Commercial-egg producers sometimes have pens 36 by 36 ft. accommodating about 470 Leghorns or 400 general-purpose layers.

Summer and Winter Ventilation. In hot weather it is necessary to have free circulation of the air through the house. An insulated roof aids in protecting the fowls against excessive heat, and windows and ventilators in the rear of the house are also very beneficial.

In southern sections of the country, laying houses are usually uninsulated and have relatively large front wall openings, provided with glass or curtains that can be partially or completely closed during a sudden lowering of outside temperature and on very cold nights.

In cold weather it is necessary to have a sufficient change of air in order to avoid excessively low temperatures in the house. In northern sections of the country, insulated roofs and side walls are considered a necessity. Insulation tends to prevent heat loss in winter and helps to maintain temperatures above freezing. In many cases the roof is insulated by providing a straw loft with a ventilated attic. The rate of change of air within the house should be sufficient to keep moisture from condensing on walls and ceilings and to keep the moisture in the litter below about 40 per cent.

In the Northeastern and some of the other Northern states, a tightly built, well-insulated house with controlled ventilation is used.

Sunlight in House. Plenty of sunlight in the house during winter months helps to moderate low temperature and to keep the litter

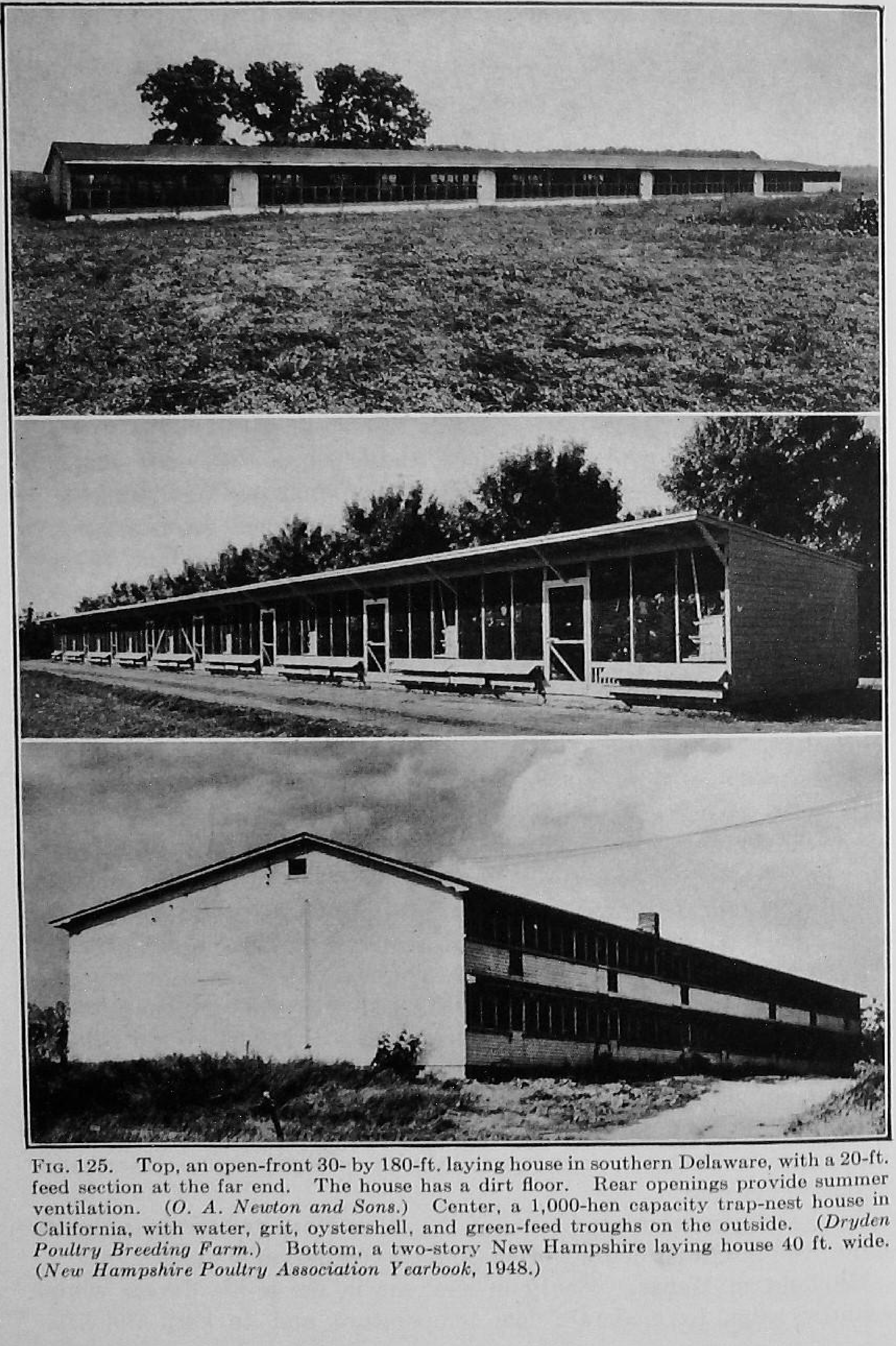


FIG. 125. Top, an open-front 30- by 180-ft. laying house in southern Delaware, with a 20-ft. feed section at the far end. The house has a dirt floor. Rear openings provide summer ventilation. (*O. A. Newton and Sons.*) Center, a 1,000-hen capacity trap-nest house in California, with water, grit, oystershell, and green-feed troughs on the outside. (*Dryden Poultry Breeding Farm.*) Bottom, a two-story New Hampshire laying house 40 ft. wide. (*New Hampshire Poultry Association Yearbook*, 1948.)

dry. Sunlight is an effective germicide and is thus beneficial to the flock.

Distribution of Light. Well-distributed daylight within the laying house encourages the birds to use all parts of the house. In northern sections of the country, the amount of window-opening space is often about 5 per cent of the floor area; too much window space allows too much heat to escape through glass or cloth when the sun is not shining. In southern sections of the country the amount of window-space opening may be as high as 25 per cent of the floor area.

In all sections of the country, a limited amount of window space in the rear of the house provides for much better distribution of light within the house.

Durability. Money spent in building a laying house should be considered as an investment in the future performance of the flock over a period of years. The cost of the house constitutes an overhead charge to be made against each flock of layers placed in the house each year. The use of durable materials and good workmanship in construction are essential to keep the cost of repairs and replacements at a minimum. A well-built roof is particularly important. This fact is appreciated when it is realized that on most farms and on all commercial-egg-producing plants, the major source of the poultry income is obtained from eggs.

At the same time, building a house more expensive than necessary to provide comfortable quarters for the birds winter and summer is unwise because the overhead charge each year is excessive.

LAYING-HOUSE CONSTRUCTION

In a book of this kind it is impossible to give detailed plans and specifications of different types of laying houses. These can be secured from the various state agricultural colleges and experiment stations. In the space available, the more important features of laying-house construction are discussed briefly.

Foundations. For a permanent laying house, a masonry foundation is desirable. It should be solid enough to support the building, whether one-story or multistory, deep enough in the ground to avoid heaving from freezing, and high enough above ground level to keep out snow and water. If the normal water level is high, or if water is liable to seep downhill to the site, it would be well to lay a drain tile around the foundation and connect the tile with an outlet to carry the water away. For all houses with concrete foundations, an 8-in. slab of concrete extending outward from the bottom of the foundation serves as a protection against rats.

For a one-story house the foundation should be at least 6 in. thick.

The depth should be as follows: in southern sections, at least 12 in; in northern sections, at least 2 ft; and in temperate sections, at least 1.5 ft.

Floors. The floor of a laying house should be free from dampness, with a smooth surface without cracks, easy to clean and disinfect, ratproof, and durable. Well-laid concrete floors more nearly meet these requirements than any other kind of a floor. Concrete floors laid on the ground conserve warmth from the earth in winter. In multistory houses naturally the upper floors must be made of lumber, double flooring with building paper between being desirable. In a one-story house, a board floor a few inches above the ground permits the loss of warmth by the circulation of cold air under the floor and makes a harboring place for rats. Sand floors are used to some extent in California, the top of the floor being about 8 in. above outside ground level.

Before preparing to lay a concrete floor, all sod and loose soil should be removed in order to give a firm base. At least 6 in. of coarse gravel or broken stone should be spread evenly over the ground and tamped firmly, or hollow building tile may be laid on top of about 3 in. of coarse gravel. A sheet of composition roofing or other vaporproof material laid on top of the gravel or tile, immediately under the floor, is an assurance against moisture from the earth. The floor is usually made of from 2 to 3 in. of concrete, with a smooth surface for easy cleaning, and sloping about 6 in. in 20 ft. to a floor drain at one side of the house, if a drain is practical. The top of the floor should be at least 6 in. above the outside grade. In sections of the country where damp weather prevails during the winter months, underfloor heating is employed to keep the litter dry.

Walls. The walls should be watertight, windproof, and finished with interior surfaces that are easy to clean and disinfect. The interior wall surfaces for 3 ft. above the floor and for 2 ft. above the perches should be peckproof. Matched boards are often used for walls, and in northern sections of the country less heat is lost from the house if heavy building paper and then shiplap or drop siding is nailed to the outside of the matched boards.

Insulation. In most parts of the United States the insulation of the roof of the laying house is advisable in order to counteract the heat absorbed by the roof in hot weather and to reduce the loss of heat from the inside of the house during cold weather. Side-wall insulation is recommended for sections of the country where the winter weather is very cold.

The most common type of roof insulation in the Middle West and northern sections of the country is straw in the gable which is provided with some ventilation. Supporting the straw on fine-mesh wire screen helps to keep out rats. Other types of roof insulation are illustrated in Fig. 126. Painting the roof with aluminum paint helps to keep the lay-

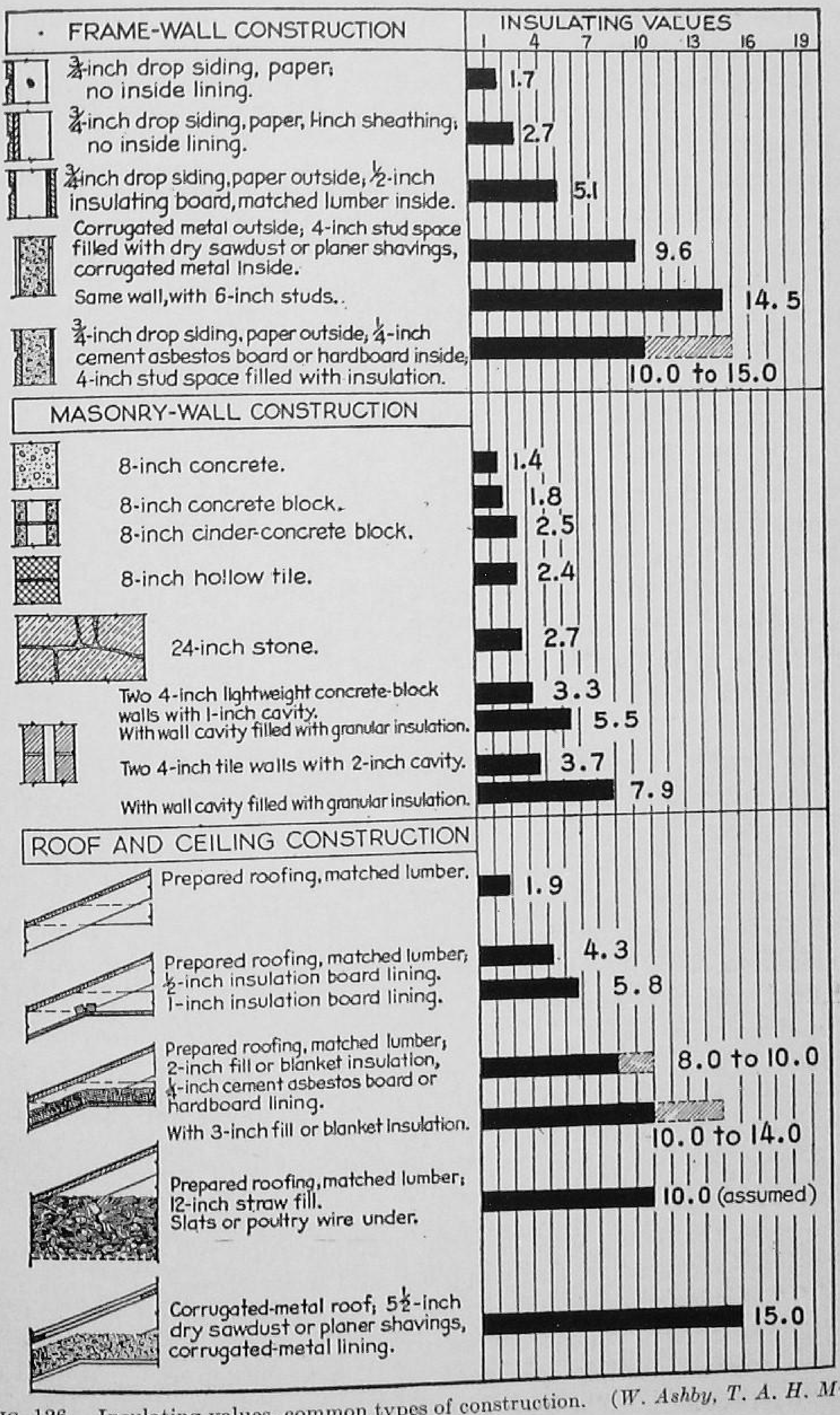


FIG. 126. Insulating values, common types of construction. (*W. Ashby, T. A. H. Miller, G. L. Edick, and A. R. Lee, U.S. Dept. Agr.*)

ing house cooler in hot weather. Aluminum sheets and aluminum roll roofing provide excellent insulation. Also, aluminum foil may be placed between the rafters. Additional insulation is provided by top-dressing the roof with a mixture of asphalt and aluminum flakes and then painting with aluminum paint.

Side walls are insulated in various ways, as indicated in Fig. 126. Side-wall insulation should be protected by a hard covering which the birds cannot peck. Also, particular precautions should be taken to prevent rats from burrowing through the insulation material.

In Fig. 126 are given the insulating values for different types of wall and roof construction, the numbers given in the right-hand column represent the number of degrees difference in temperature between the two sides of a wall which will permit 1 B.t.u. of heat to flow through an area of 1 sq. ft. of wall in 1 hr. In sections of the country where the winter is severe, the insulation of relatively small-sized laying houses is more important than in the case of large-sized houses. For instance, a 10- by 10-ft. laying house with 25 layers has 11.2 sq. ft. of wall area per bird, whereas a 20- by 20-ft. laying house with 110 birds has 5.1 sq. ft. of wall area per bird. The maintenance of the same temperature in the 10- by 10-ft. house as in the 20- by 20-ft. house would require that the wall-insulating value of the 10- by 10-ft, house be more than twice the 20- by 20-ft. house.

Vapor Barrier. In sections of the country having cold winter weather, it is very desirable to use a vapor barrier on the inside of the insulation to prevent water vapor in the air of the laying house from condensing in the insulation. Condensation of moisture within an insulated wall greatly reduces the insulating value of the insulating material.

Satisfactory vapor barriers are aluminum foil, two coats of asphalt or aluminum-flake paint, lightweight roll roofing, and shiny, heavy asphalted paper. Unsatisfactory materials are ordinary paint, tarred felt, and red resin paper.

Roofs. The greatest of care is necessary in constructing the roof of a laying house because it is relatively expensive and unless well constructed is soon in need of repair. Since it is the most exposed part of the laying house, it must withstand the hot rays of the sun, rain and sleet storms, and strong winds.

The most commonly used material is composition roll roofing, which is relatively inexpensive, easily applied, and is draftproof and moistureproof. Tongue-and-groove sheathing of good grade should be used as sheathing to prevent winds from the underside from loosening the roofing, and the greatest possible care must be used in laying the roofing. In order to reflect as much heat as possible, the roof should be painted with a

reflecting type of paint, such as aluminum paint or infrared-reflecting paints.

Slightly pitched roofs are difficult to keep watertight for a period of years unless built-up roofing is used. Built-up roofing consists of several layers of roofing paper cemented down with hot asphalt over tongue-and-groove sheathing. The first roll of roofing paper, weighing 60 lb. per sq. ft., is laid on the sheathing and nailed down tightly with cap spacing nails. From two to four additional layers of roofing paper are laid horizontal to the sheathing and cemented down with hot asphalt.

Metal roofing is used to a considerable extent because of its lasting qualities and because less lumber is required than in other types of roofing. Good roofing insulation should be installed to prevent the laying house from becoming too warm in hot weather, and the metal roof should be painted with aluminum or other heat-reflecting paint.

Doors and Partitions. Entrance doors should be at least 3 ft. wide and 6 ft. 6 in. high, preferably with a litter stop at the bottom. Doors between pens should swing either way and should have a litter stop at the bottom. In a long laying house, much time and labor are saved by using an egg carrier and a litter carrier suspended from a track. In this case, the doors between pens should be hung in pairs and be made double acting so that the carriers can be pushed through from either direction.

In long laying houses, partitions are usually spaced every 20 or 30 ft. Every third partition should be solid, the alternate ones being made entirely of wire netting or about 3 ft. solid with netting to the ceiling.

If no partitions are used or for times when partitions are removed to provide for better summer ventilation, extra braces must be built in because partitions serve an important function in the structural strength of a large laying house. In long laying houses, each pen may contain as many as 1,000 or more layers.

Windows. The primary purpose of windows is to admit light, but they are also often used to provide ventilation. In some sections of the country, in addition to glass windows located in the front of the house, there are also window openings covered with cloth to admit fresh air. Glass substitutes are sometimes used because they are easier to replace. Before glass substitutes are installed, however, careful inquiry should be made to determine whether they will admit ultraviolet light.

Glass windows in the front of the house should be installed so that they can slide up and down. Glass windows are necessary in the rear of the house in order to provide good distribution of light within all parts of the house. This is especially true in the case of deep houses. They also provide better summer ventilation of the house. They should be in-

stalled under the level of the roosts if droppings boards are used and above roost level if droppings pits are used.

Ventilators. A successful ventilating system provides a definite way for air to enter the laying house and a definite way for air to go out, and a minimum of attention is required during sudden changes in weather.

Fresh-air inlets should be baffled to direct the inflow of air upwards. It is particularly important to prevent drafts from reaching the birds while roosting.

Any one of the three following methods of ventilating a laying house may be used: (1) installing warm-air outlets by a continuous adjustable-

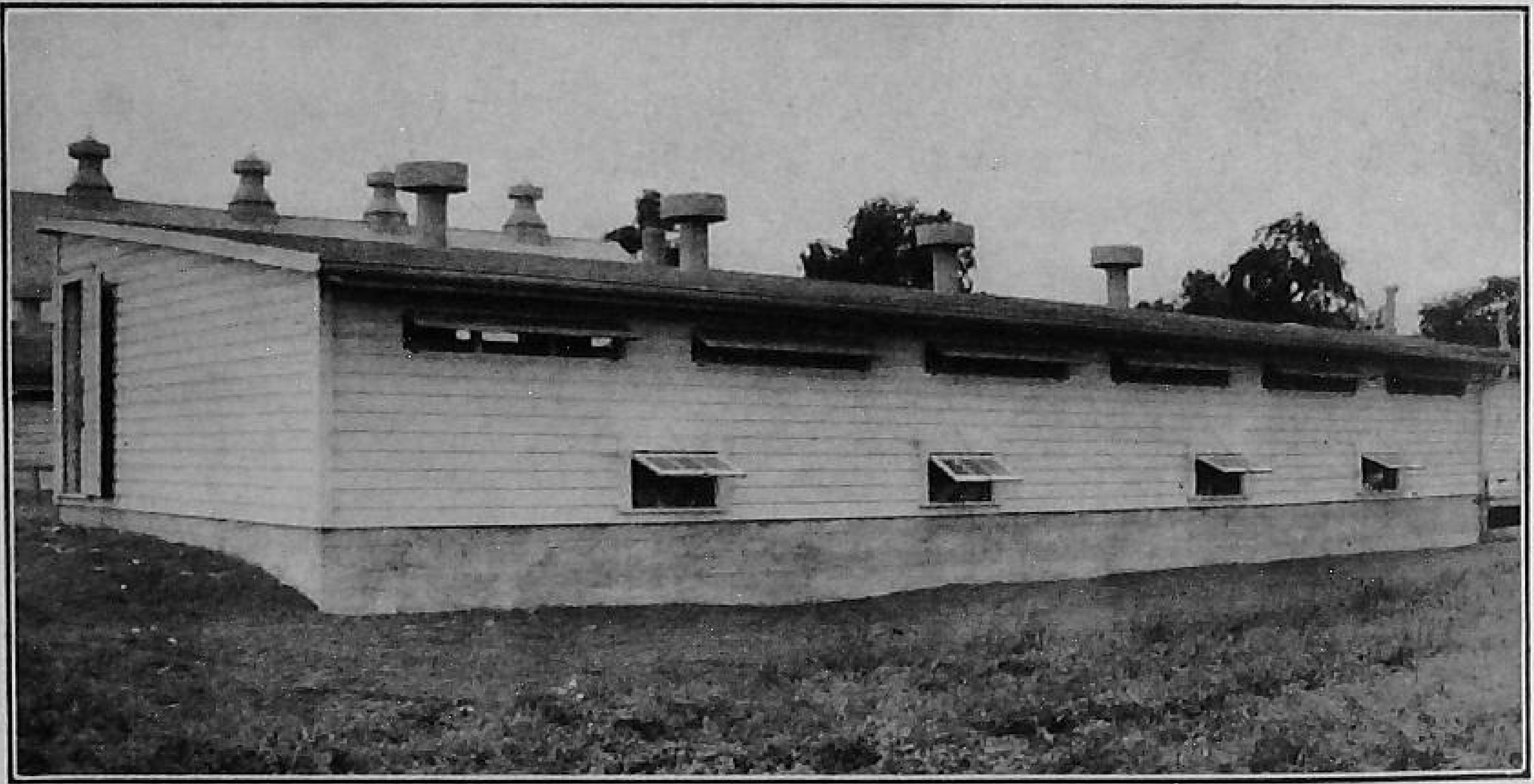


FIG. 127. Providing summer ventilation by means of hinged ventilators and windows at the rear of a laying house. (*Pa. State Coll. Ext. Service.*)

slot ventilator above the front windows; (2) installing ceiling ventilators between rafters or installing ceiling-flue outtakes; (3) installing floor-flue outtakes, the ducts extending down to within about 18 in. of the floor. In addition, ventilators are frequently used to carry warm air from the gable, between the insulated ceiling and the roof. Also, in some sections of the country, electric-fan ventilators are used, although they must be operated carefully to give satisfactory results.

The adjustable slot-ventilating system is often used in the shed-roof type of house, especially in the northeastern section of the country. Ceiling ventilators are used in shed-roof and gable-roof types of houses. Floor-flue outtakes are most commonly used in gable-roof types of houses.

LAYING-HOUSE EQUIPMENT

The laying house should be equipped with roosts, nests, feed hoppers, water containers, and other items that are durable, easily cleaned, and

disinfected whenever necessary. They should be arranged in the laying house in such a way as to provide satisfactory conditions for the birds and at the same time permit the flock owner to do the daily chores with a minimum of time and steps.

Roosts. The most popular roosts used are 2- by 3-in. or 2- by 4-in. pieces placed on edge with the upper corners rounded. The amount of roosting space to provide should be from 8 to 10 in. per bird, depending upon the breed. The roosts should be from 14 to 16 in. apart. Roosts

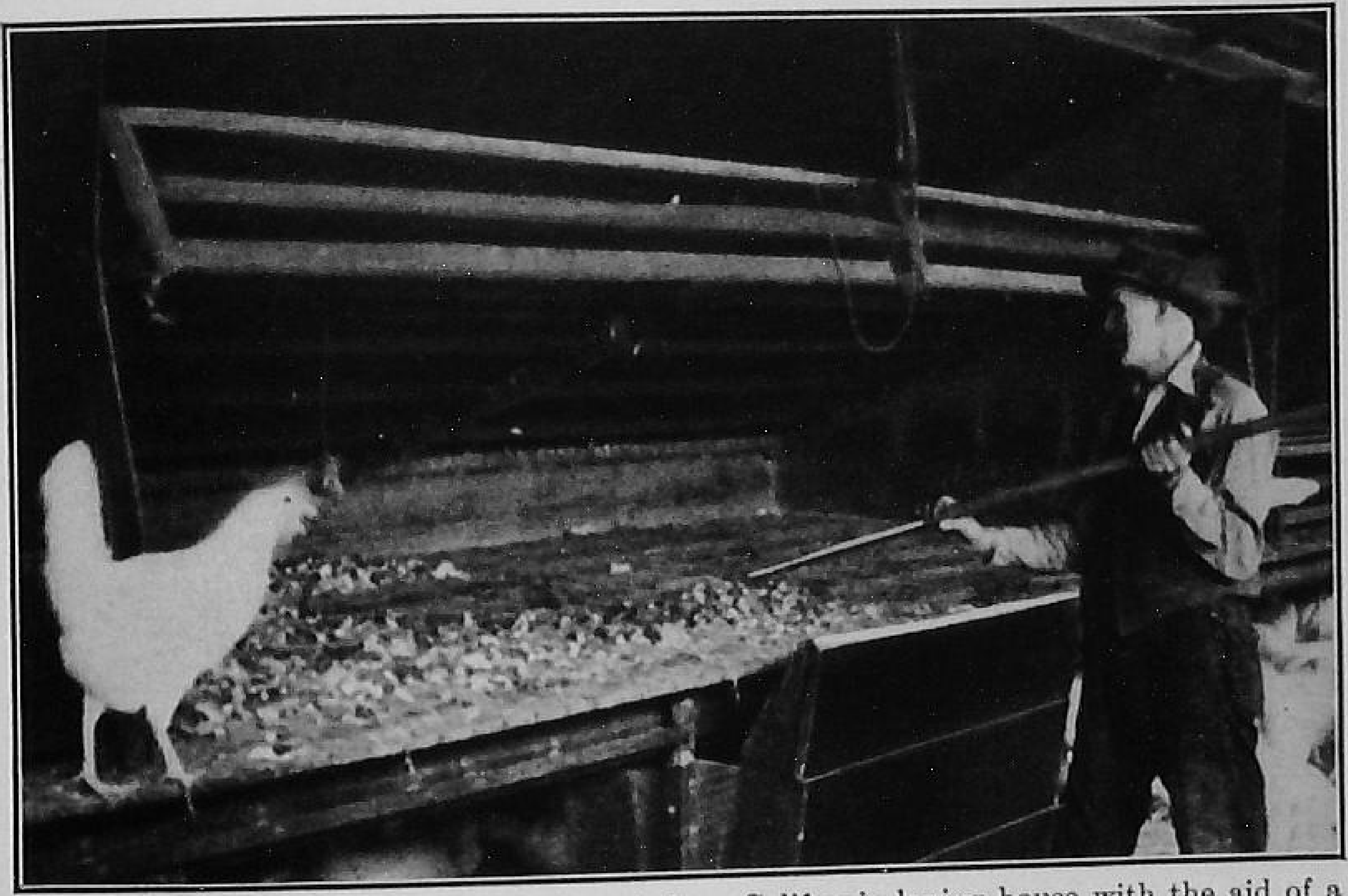


FIG. 128. Cleaning the droppings boards in a California laying house with the aid of a litter carrier. (*Nulaid News.*)

may be used in combination with droppings boards or droppings pits. In recent years, some laying houses have been built without roosts.

Droppings Boards. Roosts should be placed about 6 in. above the droppings boards with the rear roost at least 12 in. from the rear wall. The droppings boards should be made of good-quality matched lumber or composition board and they should be as free as possible of cracks. They should be built at least 2½ ft. above the floor and should preferably be made removable for ease in cleaning the rear part of the laying house. In hot weather, the droppings boards can be moved a few inches away from the rear wall of the house to provide better summer ventilation for the roosting quarters. The droppings boards should extend 8 in. beyond the area covered by the roosts.

The roosts should be built in removable-frame forms, hinged at the rear, in order that the front of the frame may be hooked to a rafter or the

ceiling when the droppings boards are to be cleaned. Immediately beneath the roosts, 16-gauge 1½-inch-wire-mesh netting or 14-gauge 1- by 3-in.-square-mesh welded wire should be nailed to keep the birds out of the droppings. This reduces the number of dirty eggs to be gathered.

Droppings Pits. The use of droppings pits instead of droppings boards seems to be on the increase, especially in the case of wide laying houses for large flocks. The sides of the pits should be from about 8 to 12 in. high, and the pits should be no wider than will permit a person to reach birds in the center at culling time.

FIG. 129. Droppings pit in first-floor laying pen of a two-story laying house on farm of G. Corbeau Jr. in Washington State. The room at the rear is a dark nesting room. Note the window ventilating device and the continuous-flow water system, with fountains in the middle of the droppings pit. (*Photograph courtesy Heisdorf and Nelson.*)

The roosts should be built in removable-frame forms, and under the roosts 16-gauge 1½ in.-wire-mesh netting or 14 gauge 1- by 2-in.-square-mesh welded wire should be nailed.

Some poultrymen use elevated droppings pits with lighting boards on the side. The bottom of the pit should be about 2 ft. above the floor of the house, and the sides and bottom of the droppings pit should be thoroughly waterproofed to prevent rotting. Elevated pits give the birds more floor space, and there is less danger from rats burrowing into the pits. In houses 30 to 32 ft. deep, the droppings pits are often located about 6 to 8 ft. from the rear wall, thus providing for better ventilation and permitting nests to be placed along the rear wall.

Nests. Nests should provide the layers with seclusion, be well ventilated, easily cleaned and disinfected, and conveniently located to save

the flock owner's time in gathering eggs. So-called "open" nests are used by most farmers and commercial-egg producers, and trap nests are used by pedigree-poultry breeders.

Open Nests. The traditional 12- by 12-in. or 14- by 14-in. boxlike nests are giving way to the tunnel or community nests which have no partitions. A satisfactory arrangement is to build the nests in 4-ft. sections with an entrance door 8 by 8 in. in the center of the front of the nest. It is important to have the bottom of the entrance door 6 in. above the nest floor in order to keep litter in the nest. The front of the nest is 13½

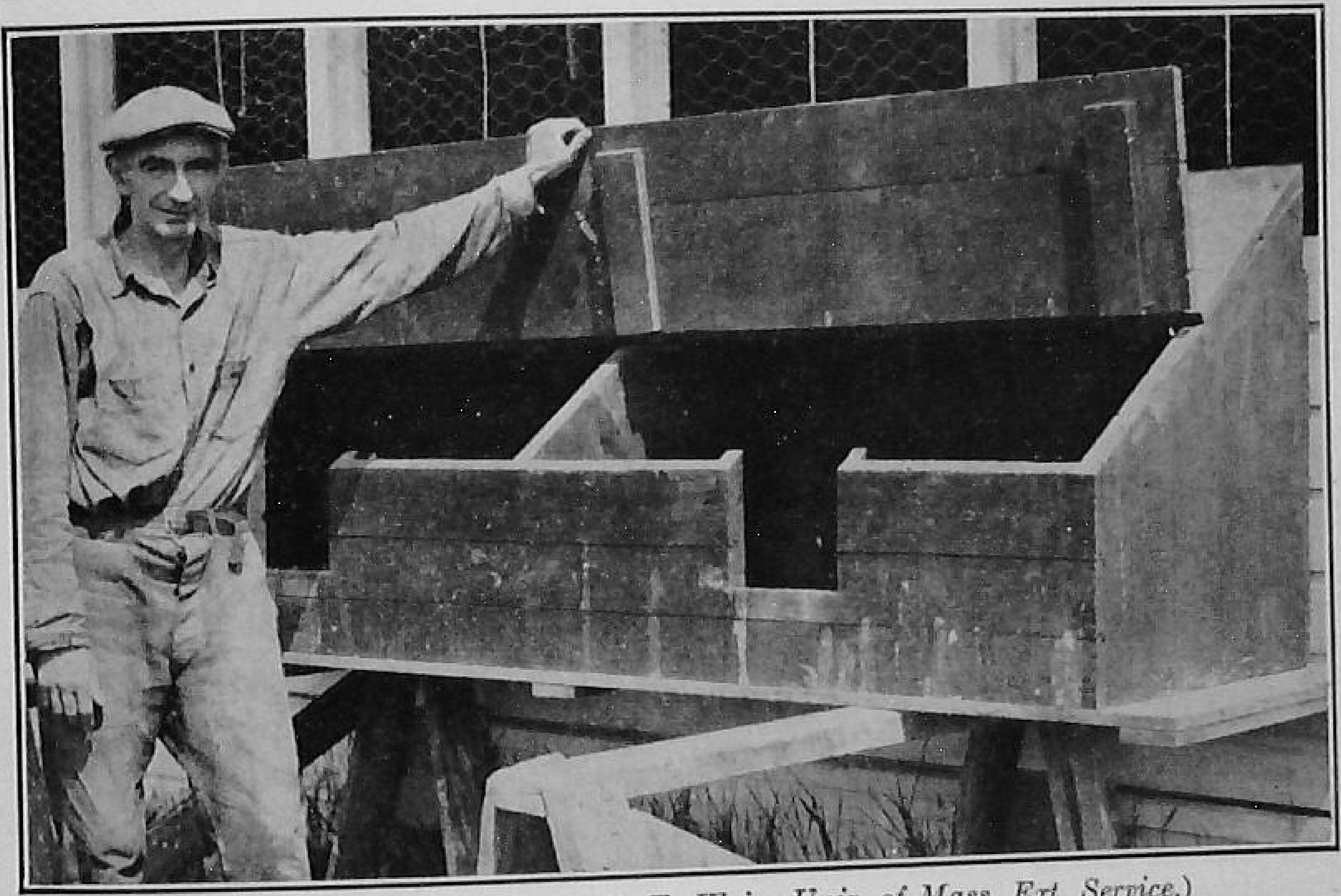


FIG. 130. A tunnel nest. (*G. T. Klein, Univ. of Mass. Ext. Service.*)

in. high, the top board being beveled to provide a tight fit with the lid. The back of the nest is 30 in. high. The nest is 24 in. wide. The top is made in two sections, 14 in. and 16 in., respectively. The front 14-in. section is hinged for gathering the eggs.

At least 6 in. of the front, ends, and back must be made of matched boards in order to keep the litter in the nest. The floor must also be made of matched boards and is usually 18 in. above the floor of the laying house. Shavings have been found to be satisfactory for nesting material. A four-section nest will provide nesting space for about 40 birds. For adequate ventilation of the nest in hot weather, it would be well to have openings at the top of the back and at the top of the ends of the nest.

This type of nest has the advantage of providing seclusion for the birds and convenience in gathering eggs and reduces breakage of eggs by the birds. It also minimizes egg eating by the birds.

Trap Nests. Each nest is provided with a trap door so that when the poultryman releases the hen from the nest he can identify her and mark her leg-band number on the egg. The trap doors should be in perfect condition at all times, and trap nests should be well ventilated in hot weather. This can be accomplished by using hardware cloth at the rear of the nest and hardware-cloth partitions, if necessary. There should be one nest for every three or four birds.

Feed Hoppers. The essential features of satisfactory feed hoppers are that they (1) avoid wastage of feed, (2) prevent the birds from getting

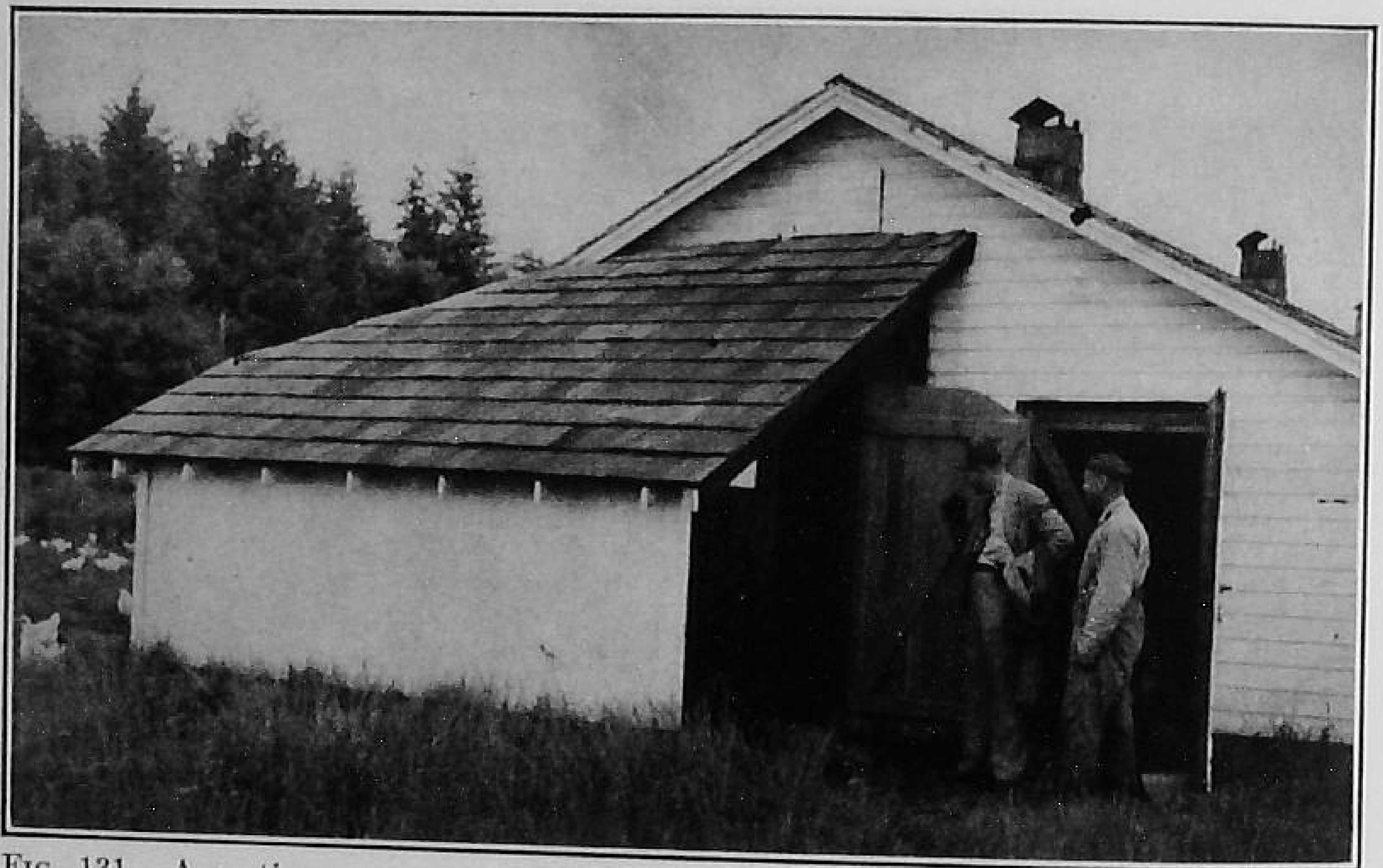


FIG. 131. A nesting room attached to a laying house in Washington State. (*Pacific Poultryman.*)

their feet into the feed and from roosting on the hopper, (3) are easy to clean, and (4) make it easy for the birds to eat from the bottom of the hopper. The feeding space available should be at least 1 ft. per four birds, and for convenience in cleaning each hopper should not be more than about 6 ft. long. A light perch attached to each side of the hopper enables the birds to stand comfortably while eating.

In many flocks, males will fare better if a special feed hopper is provided for them out of the reach of the females.

Grit and oystershell are usually provided in separate hoppers.

Water Containers. An ample supply of water should be available at all times, or egg production is liable to be affected. The water container should provide clean water, keep the water cool in summer, and be easily cleaned because contaminated water tends to spread certain diseases from bird to bird.

Water containers should be designed so that as little water as possible is spilled on the litter; supporting the containers on wire platforms will help to keep the litter dry. It should be impossible for the birds to scratch litter into the water container or contaminate the water with their droppings. In hot weather the water should be kept cool, and in very cold weather it should be kept from freezing. For the latter, the use of electric heating devices is increasing in popularity.

Galvanized pans or pails make satisfactory water containers when a continuous supply of running water is not available. The amount of

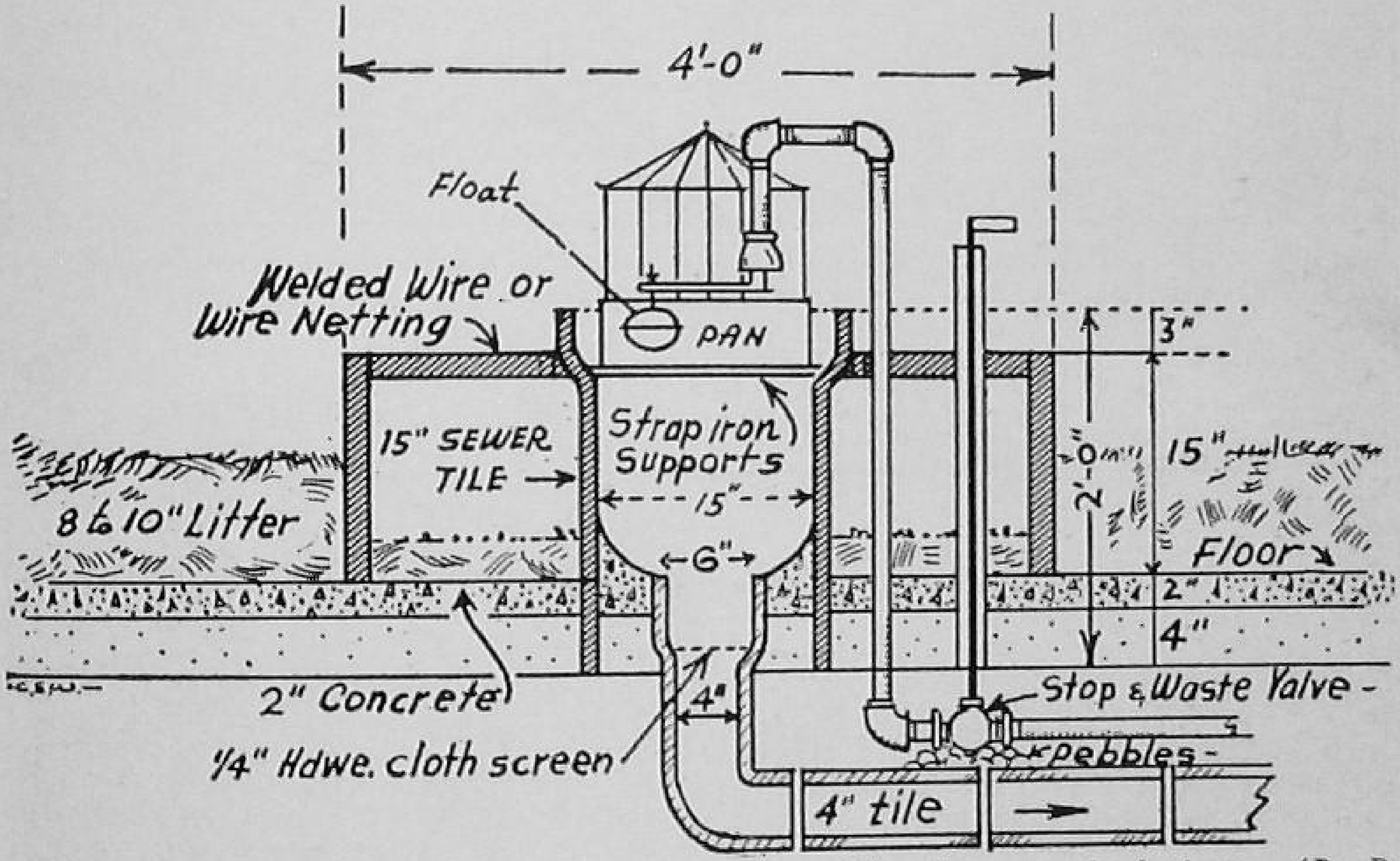


FIG. 132. Detail drawing of automatic waterer with wire-covered platform. (*D. D. Moyer and V. Overholt, Ohio Univ. Agr. Ext. Service.*)

water that must be supplied daily depends upon the size of the birds, the weather, the level of egg production, and the salt content of the diet. During the hot weather 100 hens will consume about 7 gal. of water daily and during cold weather about 5 gal.

Automatic fountains save an enormous amount of labor in watering even a small flock in a year. Where temperatures in the house may go below 32°F., the water containers should be of the nonfreezing type and the water pipes must be protected. For this purpose, soil-heating cable may be used, but it must be properly installed, with proper ground connections. The thermostat is adjusted to turn the electric current off at the desired temperature to prevent the pipes from freezing.

Broody Hen Coops. The sooner that broodiness is "broken up," the sooner the hen that has been broody starts laying again. The broody coop should have a comfortable wire floor and be provided with feed and water containers.

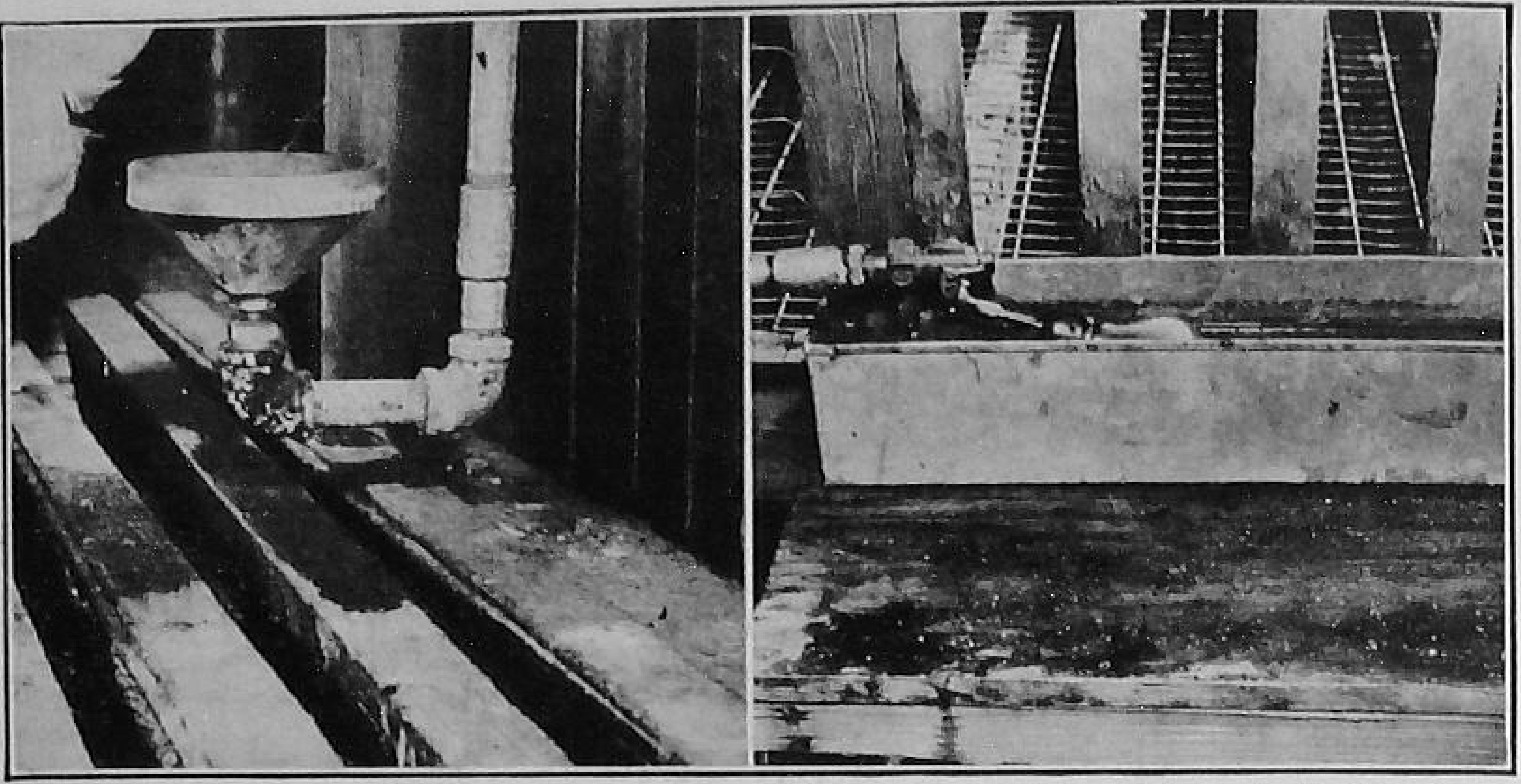


FIG. 133. Left, controlled flow-cup waterer. Right, trough with valve controlled by float. (*H. L. Belton and V. S. Asmundson, Calif. Agr. Exp. Sta.*, 1949.)

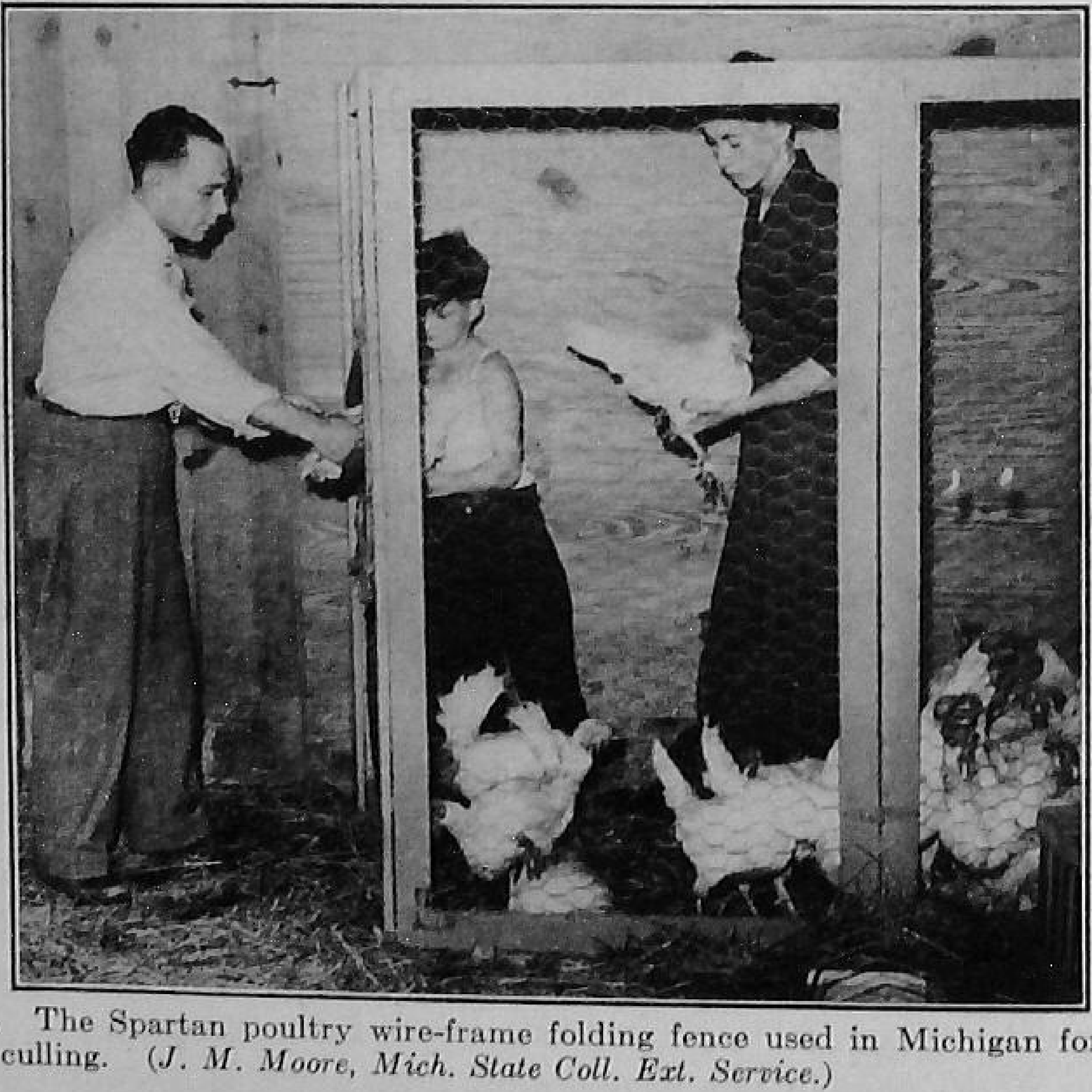


FIG. 134. The Spartan poultry wire-frame folding fence used in Michigan for catching birds for culling. (*J. M. Moore, Mich. State Coll. Ext. Service.*)

Culling Equipment. The regular culling of the laying flock is an important part of successful flock management. A certain amount of culling may be done at night with an electric-light bulb, but for extensive culling, much time is saved by using wire frames, hurdles, or cotton netting to catch the birds without unduly disturbing them.

Artificial-lighting Outlets. It is a common practice to use artificial lighting to stimulate fall egg production when pullets are placed in the laying house. Also, yearlings are often lighted to secure as many eggs as possible before the first annual molt.

Fig. 135. A crate for catching chickens. At each end there is a sliding door that can be raised, and there is a sliding door at the top. (*U.S. Dept. Agr.*)

Lighting fixtures should be installed to provide one 40-watt bulb for each 200 sq. ft. of floor space. The light should be placed in the middle of the pen from end to end and over the feed hoppers and water containers. The reflector should be about 4 in. deep and about 16 in. in diameter. In houses 30 to 32 ft. wide with roosts near the center of the pen, one row of outlets should be placed midway between the front of the house and the roosts and another row midway between the roosts and the rear of the house. Approximately 15 kilowatt-hours per month per 100 birds is sufficient.

Feed and Litter Carriers. In long laying houses, feed and litter carriers save much time and labor in feeding the birds and renewing the litter. Time is also saved in gathering eggs by using the feed carrier.

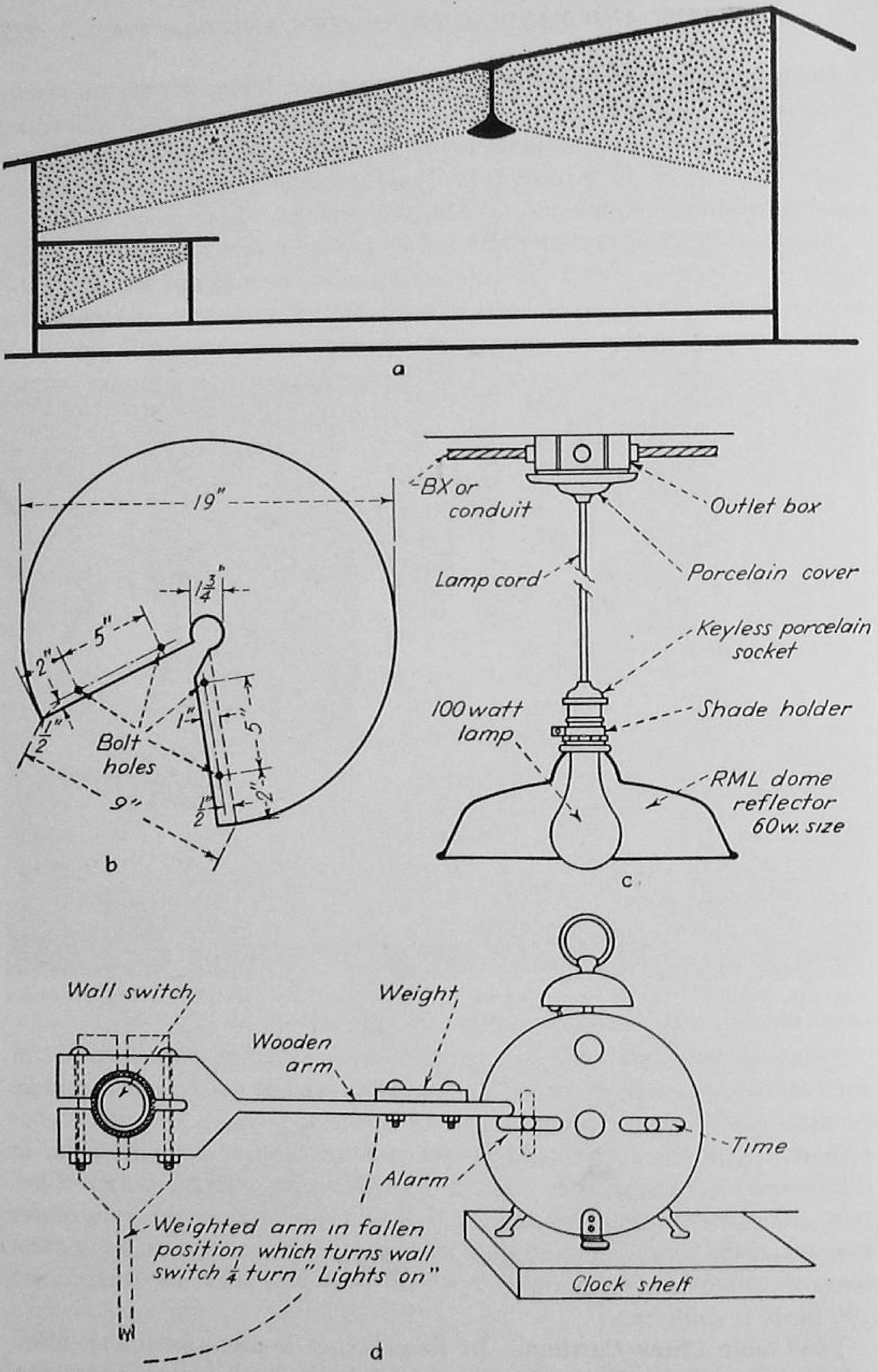


FIG. 136. Installing lighting system: (*a*) correct location for lighting (*R. E. Cray and H. P. Twichell, Ohio Agr. Ext. Service*); (*b*) pattern of reflector; (*c*) conical reflector for 100-watt and 60-watt lamps (*Knowlton, Colby, and Price, Ore. Agr. Ext. Service*); (*d*) alarm clock operates a gravity light switch for turning on the lights (*W. E. Poley, S.D. Agr. Coll.*).

Feed Room. Feed readily available in a feed room at one end or in the center of the laying house is a timesaving convenience. The feed room should be ratproof and should be kept free of live and dead birds.

Egg Room. When a large-sized flock is maintained, it is a matter of convenience to have an egg room in the laying house or adjacent to it. This serves the purpose of holding each day's production until it can be taken to the egg-holding room. The egg room in the laying house should be thoroughly insulated so that a temperature of approximately 50°F.

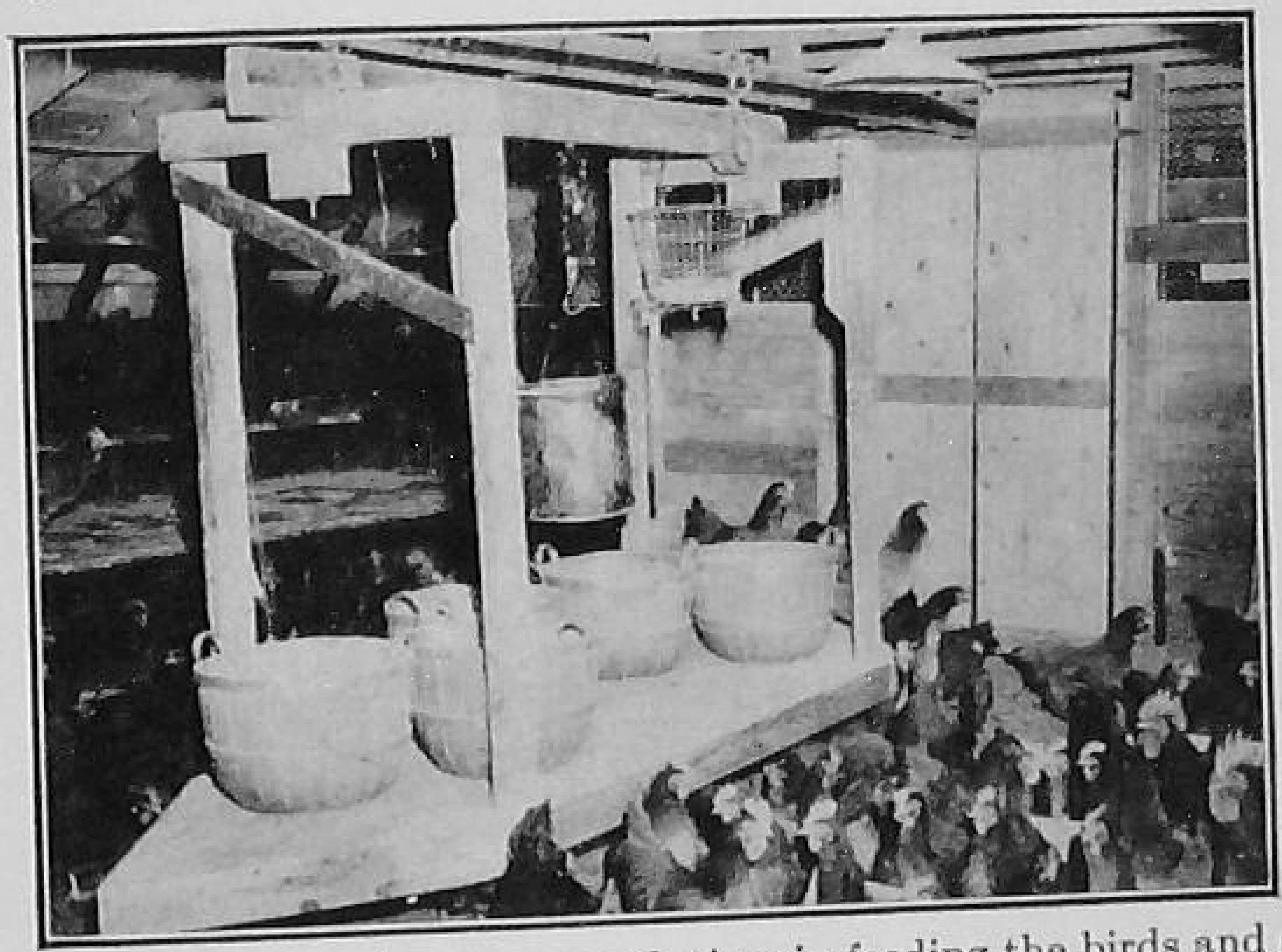


Fig. 137. A feed and egg carrier saves much time in feeding the birds and gathering eggs. (*New Hampshire Breeder.*)

may be maintained. Wire egg baskets, with the wire covered with rubber, help to decrease egg breakage in gathering eggs and bringing them to the egg room.

HOUSE-MANAGEMENT PRACTICES

A well-constructed and equipped laying house will not compensate for mediocre yields in egg production resulting from negligence in adjusting windows and ventilators in relation to changing weather conditions and otherwise doing everything possible to provide optimum housing conditions at all times.

Housing Pullets. The laying house should be thoroughly cleaned and disinfected before the pullets are transferred to it from the range. The pullets should be moved with as little disturbance as possible, preferably on a relatively cool day. If they are housed before the middle of the afternoon, they will have sufficient time to adjust themselves to their new quarters and are likely to take to the roosts the first night. For the first few nights, however, the house should be visited at roosting time to make sure that all the pullets are on the roosts and are not sitting on the nests, feed hoppers, or window sills.

House Temperature and Ventilation Control. Careful attention must be given during the colder seasons of the year to the adjustment of curtains, windows, and ventilators particularly to avoid sudden temperature changes within the house and still provide uniform air movement through the house without drafts.

In the winter and in early spring and late fall, when weather conditions are changeable, the windows and ventilators in the rear of the house should be kept closed. When the outside temperature starts to drop in the colder seasons of the year, the windows in front should be kept closed in order to retain as much heat as possible. Artificial heat has been tried as a means of preventing the inside temperature from going below freezing, but, for the most part, this practice has not been entirely successful.

In order to avoid the danger of frozen combs during very cold winter nights, some poultrymen make a practice of dubbing the combs, especially of males, in the fall. The fertility of hatching eggs is apt to be quite low in a flock in which the males' combs are frozen.

In the summer, the rear windows and ventilators and the front windows should be kept wide open. In hot weather, it is also advisable to keep the doors in the ends of the house open, the layers being confined to the house by wire doors if necessary.

The Litter Problem. Litter on the floor of the laying house is useful the year round, but in the colder seasons of the year the main problem is to maintain the litter in a satisfactory condition. Even when windows and ventilators are adjusted in relation to outside weather conditions, the litter tends to remain quite damp. This is due to the large quantities of water voided in the droppings and to the difficulty of adequately controlling ventilation to remove excessive atmospheric moisture from the house. Providing underfloor heat has been tried in some cases, and while it tends to keep the litter relatively dry it can hardly be recommended for most farm laying houses.

Kinds of Litter. The most common kind of litter used in farm laying houses is straw. In commercial laying houses as well as in many farm laying houses other materials used as litter include shavings, sawdust, oat hulls, peat moss, cotton balls or shells, ground corncobs, shredded cornstalks, and shredded sugar cane. Peat moss, straw, and shredded sugar cane have relatively the greatest moisture-absorptive ability and shavings and oat hulls the least. The choice of litter material depends upon its availability and relative price.

Built-up Litter. One of the most effective ways of keeping litter in a reasonably satisfactory condition during cold weather is by the built-up litter system. It has been the common experience of most flock owners that in the fall and winter months a thin layer of litter became quite damp

and packed in a short time. Cleaning out the house and renewing another thin layer produced the same results. Partly as a method of saving labor and partly in an attempt to maintain a relatively drier litter, the built-up litter system was adopted. The ceiling should be at least 7 feet above the floor in order to allow doors to be opened and closed.

When the pullets are placed in the laying house in the fall, the floor should be covered with about 4 in. of absolutely dry litter, or better still with a first 2-in. layer of dry shavings, dry sawdust or granulated corn-

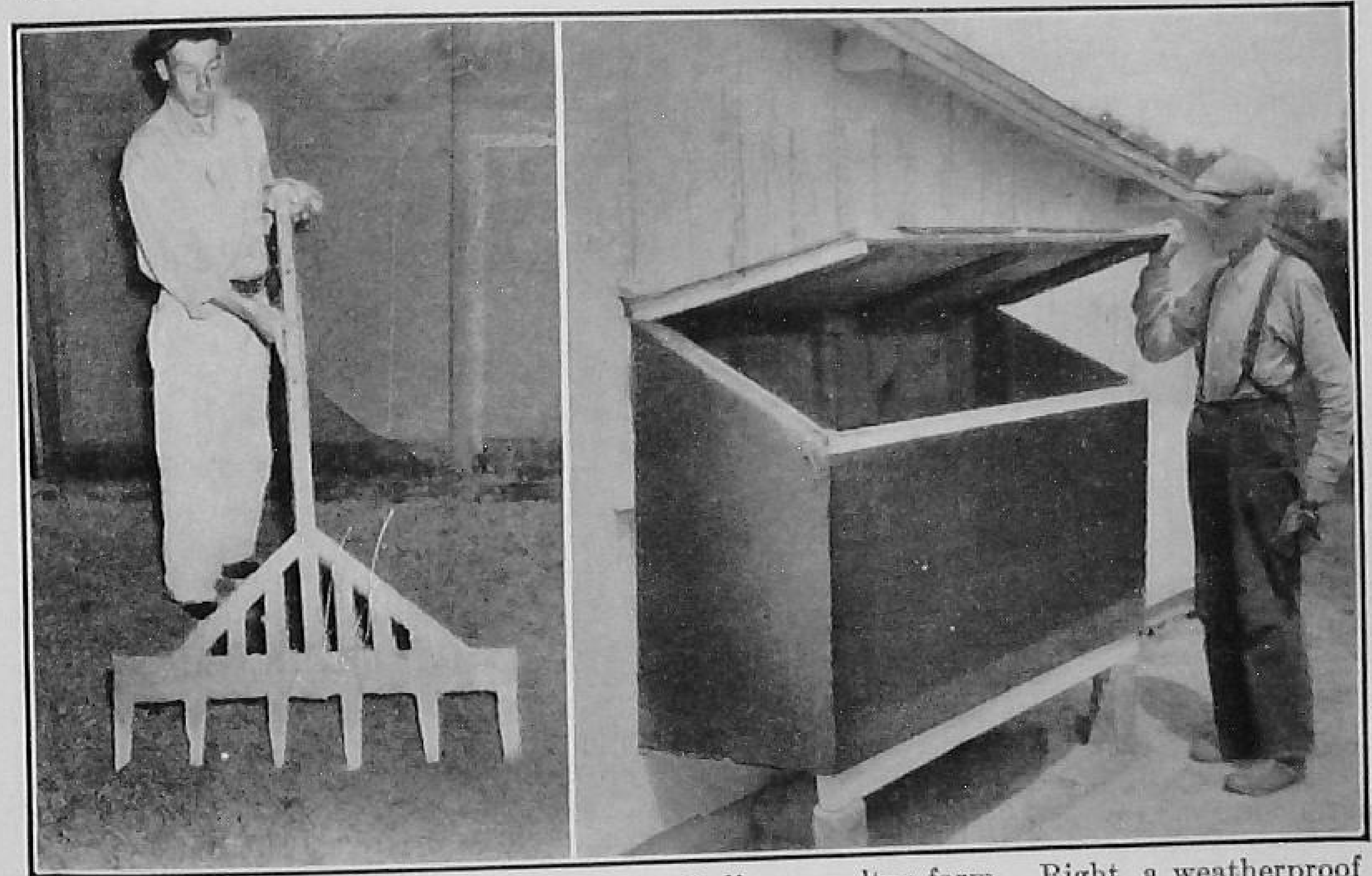


FIG. 138. Left, a litter stirrer used on an Indiana poultry farm. Right, a weatherproof outside feed bin attached to a laying house on an Illinois farm; the bin saves space inside the house, and time is saved in feeding. (*Poultry Tribune.*)

cobs on top of which is placed a 2-in. layer of straw or other litter. As the top layer of litter becomes broken up and mixed with the finer material, more litter is added at frequent intervals until the litter is about 6 to 10 in. deep. This should be done prior to cold weather. The litter should be stirred frequently, and damp litter around water containers should be removed. During the winter months, the litter should be stirred rather frequently. In the spring, the house may be cleaned and a suitable amount of litter renewed.

Some poultrymen use the same litter 2 or 3 years in succession, but for most flock owners this practice is hardly to be recommended because of the possible spread of disease to the new flock of pullets housed each year.

Limed Litter. The practice of stirring hydrated lime in built-up litter tends to keep the litter in better physical condition by reducing its

tendency to pack down or become clumpy. When the litter is about 4 in. deep, 25 lb. of hydrated lime per 100 sq. ft. of floor space should be spread over the litter and stirred thoroughly into the litter with a fork or rake. Additional applications could be made during the winter months, if necessary. Under no conditions should pulverized quicklime be used because of the possibility of fire burning down the laying house.

Poultry Manure. The laying stock produces large quantities of manure per bird, and since it is relatively rich in nitrogen, the manure is an excellent source of plant-food material. If it is allowed to decompose, however, much of its fertilizing value is lost, due to the nitrogen being liberated as ammonia.

The amount of manure produced per layer is influenced by her size, the amount of feed consumed, and other factors. Under average conditions, however, it is safe to assume that in most flocks about 150 lb. of fresh manure are produced per layer per year. At this rate, a flock of 100 birds would produce about 7 tons of fresh manure in 1 year, and 1,000 birds about 70 tons in 1 year. In the case of birds confined to the laying house throughout the first laying year, these quantities would be available if the manure was collected promptly. About two-thirds of the manure produced is deposited in the litter and about one-third on the droppings boards or in the droppings pits. Since the manure is allowed to accumulate for varying lengths of time, it loses considerable moisture. In the case of birds allowed access to yards, relatively smaller quantities of manure would be deposited in the laying house to be made available for use on the land.

The proper preservation of poultry manure is important not only to preserve its nitrogen content but also to reduce to the minimum the odor of ammonia in the laying house during the winter months. Strictly fresh manure contains about 85 per cent moisture, but manure scraped off of the droppings boards daily in the winter time contains about 78 per cent moisture, 1 per cent nitrogen, 0.8 per cent phosphoric acid, and 0.5 per cent potash. There is no loss of phosphoric acid and potash as a result of decomposition, but the loss of organic matter and nitrogen is very great, especially during warm weather.

One of the most effective methods of preserving the fertilizing value of poultry manure is to sprinkle superphosphate of the 20 per cent granular grade over droppings boards or droppings pits at the rate of about 4 lb. weekly per 100 birds. Hydrated lime reduces nitrogen losses and is a deodorizer and may be sprinkled over the droppings boards or droppings pits at the rate of about 2 lb. per day per 100 birds.

For use on crop land, 2 tons of poultry manure plus 600 lb. of 20 per cent superphosphate equals about 1 ton of 4–10–2 fertilizer. One ton of

the above mixture plus 260 lb. of muriate of potash equals 1 ton of 4–10–10 fertilizer.

Fly Control. Manure attracts flies, which multiply rapidly and are a nuisance. Lime sprinkled over the manure on the droppings board or in the droppings pit will help to control the fly menace to some extent. A more effective method is to spray the roosting quarters and accumulating manure with a solution of DDT, which should be used with discretion to avoid the possibility of poisoning humans.

Laborsaving Chore Route. Most farmers do not give sufficient attention to the arrangement of feed hoppers, water containers, and nests

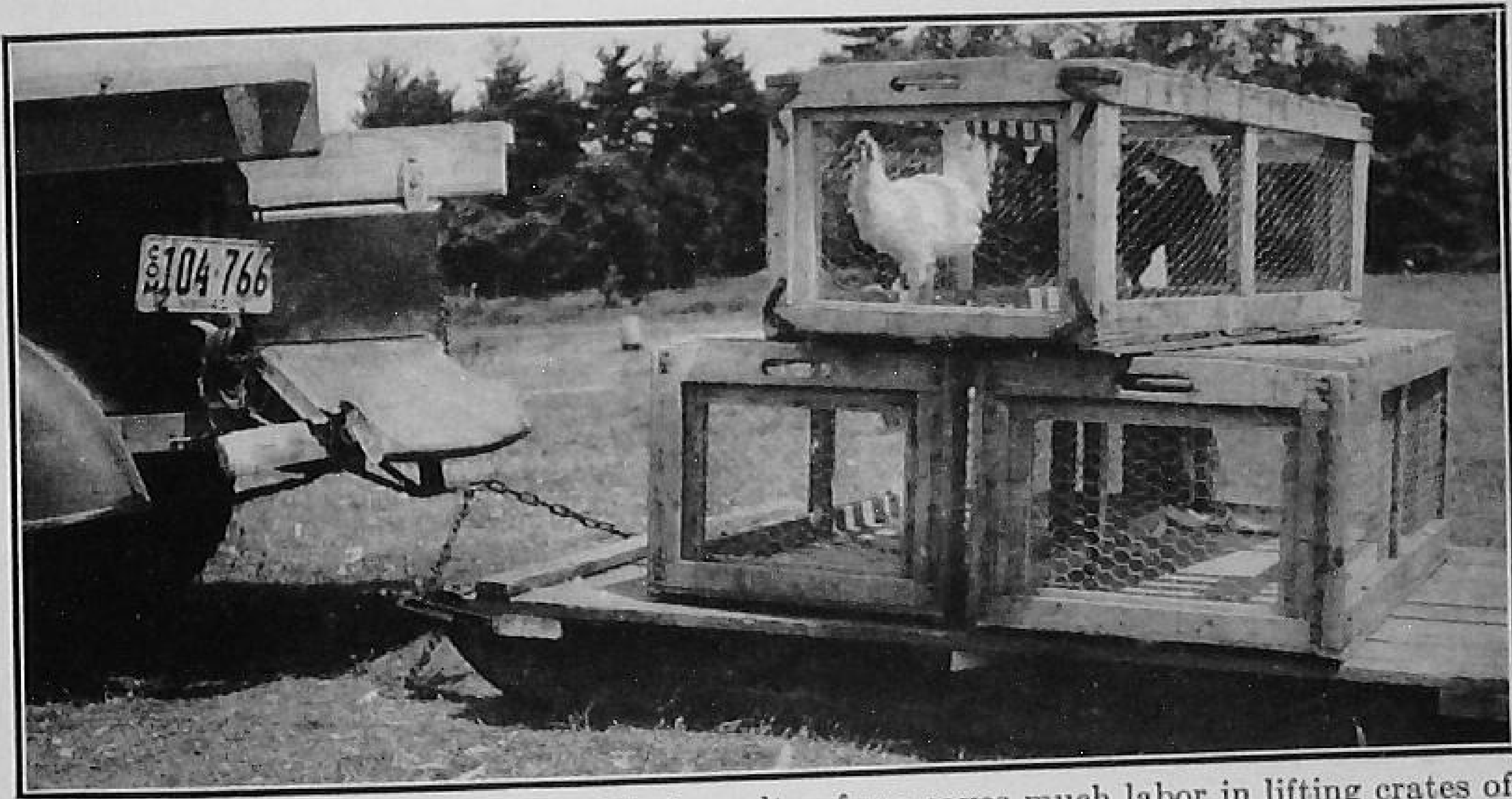


Fig. 139. A sled used on a New York poultry farm saves much labor in lifting crates of chickens at culling time. (*L. M. Hurd, N.Y. Agr. Ext. Service.*)

with a view toward saving as many steps and as much time as possible in doing poultry chores. This is especially liable to be true if the farmer's wife or the children take care of the flock. Also, in many cases labor-saving conveniences are often overlooked.

Suppose that the farm laying house is located 500 ft. from the nearest pump or water faucet and that pans serve as water containers. The pans should be emptied, cleaned, and refilled every day. The day's supply of water is carried to the laying house at the time of the first visit to the house in the morning. If there is an average of 200 birds in the house during the year, the attendant will have carried over 9 tons of water and the distance traveled would have been over 34 miles. A little investment in piping and a relatively small amount of labor involved in digging a trench and providing running water and an automatic watering fountain would save much time and labor in providing water for 1 year, to say nothing of 5 or 10 years.

The daily laying-house chores include feeding scratch grain, putting mash in the feed hoppers or stirring it up, in some cases feeding wet mash or pellets, providing water or cleaning the water containers, adjusting windows and ventilators during the colder seasons of the year, and gathering eggs.

The proper arrangement of feed hoppers, water containers, and nests saves many steps and much time in a year. Doing as many jobs as can be done efficiently on each visit to the house saves much time.

A study was made of the time required and distance traveled in doing daily poultry chores on eight poultry farms in central New York. The daily time required and distance traveled by the most efficient and the least efficient poultryman in doing poultry chores are given in Table 33.

TABLE 33. TIME REQUIRED AND DISTANCE TRAVELED BY THE MOST EFFICIENT AND THE LEAST EFFICIENT POULTRYMAN IN DOING POULTRY CHORES PER 1,000 LAYERS PER DAY

(L. M. Hurd and I. R. Bierly, Cornell University, 1947)

Kind of chore	Most efficient	Least efficient
Time gathering eggs, min	10.3	49.1
Distance traveled gathering eggs, ft	642	2,925
Time to do all feeding, min	8.7	62.7
Distance traveled to do all feeding, ft	842	4,691
Time watering, min	0	34.6
Distance traveled watering, ft	0	2,891
Time to do all chores, min	20.6	110.0
Distance traveled doing all chores, ft	1,613	7,746

It is obvious from the data given in Table 33 that the arrangement of the feed hoppers, water containers, nests, and such conveniences as running water are factors affecting the efficiency of doing the daily poultry chores. Naturally size of flock is a factor, but in most flocks it is possible to save time, steps, and labor by proper planning.

Feather Picking, Cannibalism, and Egg Eating. Any one of these bad habits may result from improper management. Feather picking and cannibalism rarely develop in a flock given access to range. Overcrowding and improperly balanced diets may be factors that give rise to these vices, although they may break out in almost any flock that is kept in strict confinement. Lack of sufficient feed-hopper space may be a factor.

Birds from which feathers have been pulled and whose bodies have been picked should have an anti-pick salve applied to the picked areas. It may be well to isolate the picked birds from the flock for a few days.

Cannibalism usually results from continued picking by members of the flock of the exposed cloaca of a bird immediately after she has laid an egg. The cloaca and portions of the intestines may be eaten, so that the bird succumbs.

Anti-pick guards attached to the beaks of pullets at housing time are used by some poultrymen. Ground oats added to the mash or good heavy whole oats fed with corn and wheat in the scratch portion of the diet will help to prevent feather picking. A better preventive measure apparently is to add salt to the diet, amounting to about 1 per cent of the mash. If the trouble does not stop within about 1 day, up to 2 per cent of the mash may be salt. This amount of salt should not be fed more than 3 or 4 days. As an alternative, 2 oz. of salt per gal. of drinking water may be used for 2 days. Steamed alfalfa may be fed, also fresh cow manure. Another effective method of controlling feather picking and cannibalism is to debeak the offenders by cutting the upper mandible back to about the quick, which can be done with a knife or with a commercial debeaking instrument. If the layers have been debeaked severely, it is advisable to feed scratch grain in mash hoppers for some time.

Egg eating is usually nonexistent where darkened nests are used.

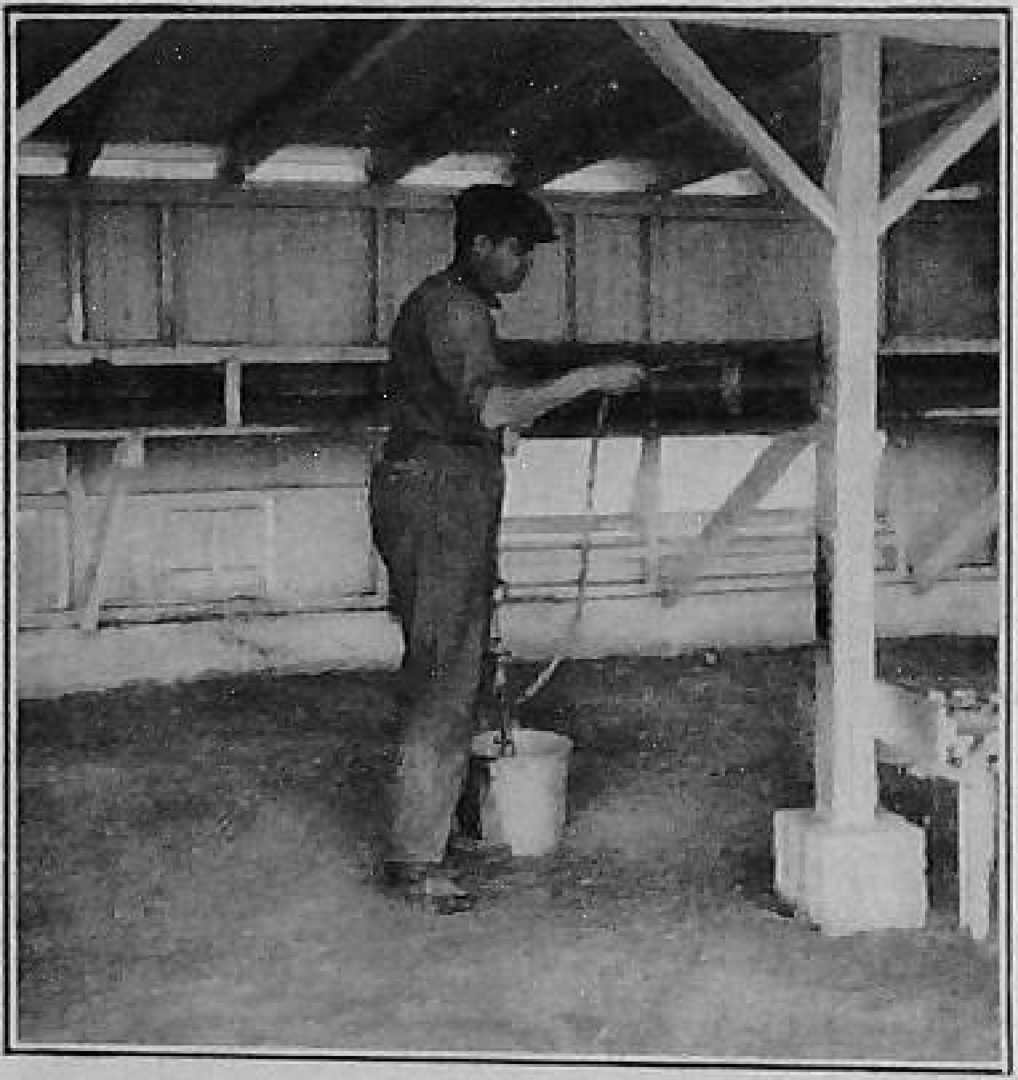
Yards for Layers. Most laying flocks are given access to range when green herbage is available. The tendency to keep the laying stock confined the year round is increasing, however, especially on the part of commercial-egg producers. Bare ground over which the birds have run for some time, mud puddles, and stagnant water are objectionable because they tend to spread disease and the number of dirty eggs is increased.

The poultry part of the farm organization should be regarded as one of the farm units and should be treated as such. On many farms the cash income obtained from poultry exceeds that obtained from each of several grain crops, several acres being used in the growing of each of these crops. Setting aside sufficient land for yards of limited size for the poultry plant is thoroughly justified and should prove to be a good investment in increasing the returns from the poultry flock.

The growing stock should be kept separate from the adult stock because of the possibility of transmitting disease from the adult to the young stock and because the land on which the adult stock has been allowed to run for several years is liable to be badly infested with parasites and disease organisms. Results secured at Cornell University indicate the great importance of rearing growing stock at a considerable distance from adult birds in combating mortality from the avian-leukosis complex (range paralysis). Chickens and turkeys should be kept sepa-

rate, for the simple reason that the former may become infected with the "blackhead" organism common to turkeys, and turkeys may become infected with a rather common chicken disease. Also, all chickens should be kept separate from swine, especially in the midwestern sections of the United States where it has been shown that swine sometimes become infected with avian tuberculosis organisms.

The mortality that usually occurs in adult stock may be materially reduced by providing the birds with an alternate yarding system. Probably the best arrangement is to provide each laying house with three yards which the birds would be allowed to use every 3 or 4 weeks. By



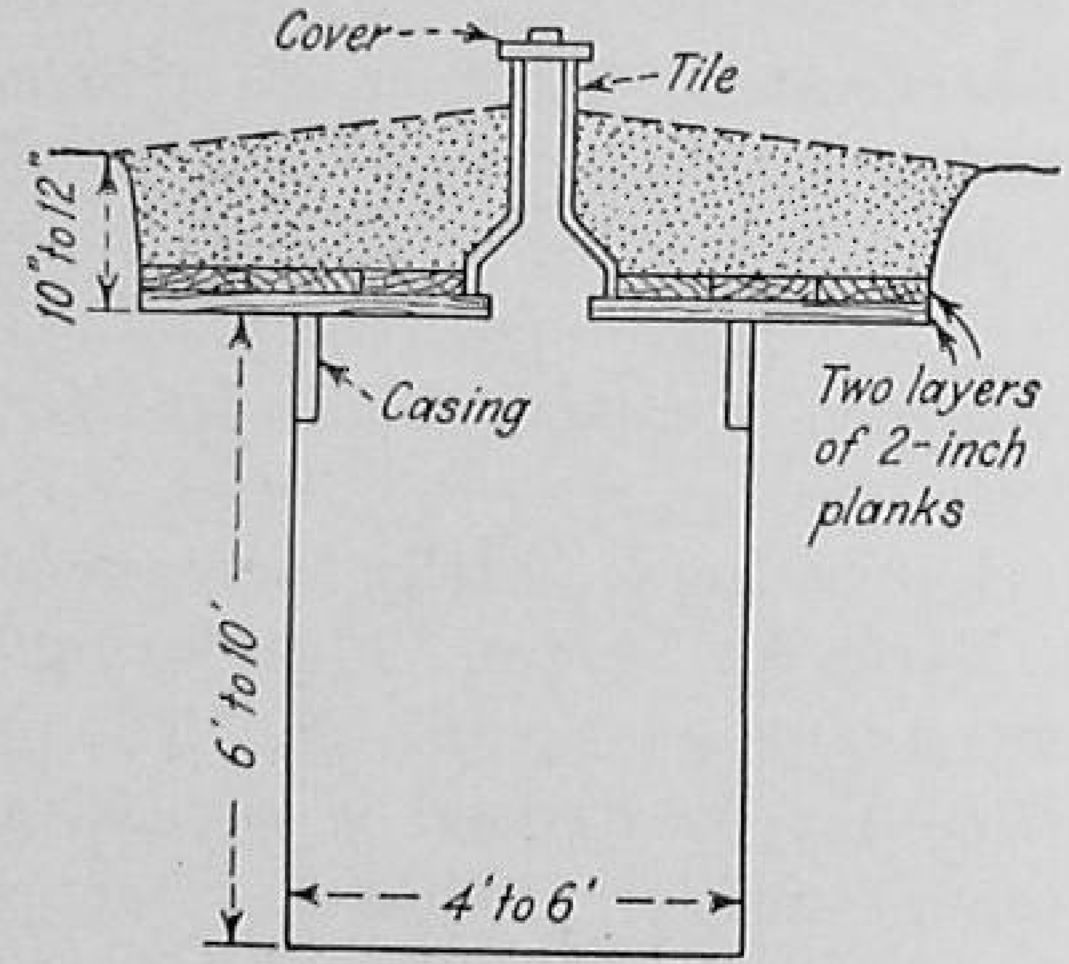


FIG. 140. Left, disinfecting the laying house with a hand spray pump. (*U.S. Dept. Agr.*) Right, a poultry pit for disposing of dead birds.

alternating the birds in the yards every 3 or 4 weeks, each yard is kept reasonably sanitary, especially if the soil in the immediate vicinity of the house is cultivated and treated with lime and young green grass is available for the birds throughout the season. For layers, a good grass sward can be maintained on fertile soil, allowing about 200 birds to the acre.

KEEPING LAYERS IN CAGES

Partly as the result of high mortality which has occurred in many laying flocks kept in the ordinary type of house and partly because of the high cost of land in certain sections, many poultrymen have adopted the system of keeping layers in cages. The diet of birds thus confined must be much more carefully balanced than in the case of birds that have access to sunlight and a good grass range. Nevertheless, under proper conditions, it is possible for some poultrymen to operate a laying-cage

system successfully and profitably, provided the overhead costs and maintenance expenses are not excessive.

As compared with the conventional floor method of keeping layers, keeping them in cages has three advantages: (1) The litter problem is avoided; (2) losses from cannibalism are avoided; (3) there are fewer dirty eggs. On the other hand, there are three disadvantages: (1) The initial cost of the building and cages is relatively high; (2) the cost of replacement is high; (3) there are more cracked eggs.

FIG. 140A. Layers in cages on an Ohio poultry plant. (*A. R. Winter.*)

Houses for Laying Cages. The proper type of house for laying cages is relatively more expensive than the ordinary type of house, because the ceiling must be higher and the house should be better insulated than is necessary in most of the houses where chickens are kept on the floor. Of course, there are no nests, roosts, or droppings boards to be provided, but these items are in many cases more than offset by the expense of the laying-cage units. Keeping layers in cages is common practice in parts of California, the cages being in single tiers housed in houses or sheds of simple design.

In northern parts of the country, the building should be of a size and shape to accommodate the particular style and number of laying-cage units to be installed, allowing plenty of room for the aisles and at the ends of the cages. A feed room, an egg room, and a storage room should be

located convenient to the laying-cage room. The ceiling of the laying-cage room should be about 10 ft. high in order to provide for adequate ventilation. The windows should be placed so that they can be opened if necessary for ventilation purposes and at the same time allow for proper lighting. The walls should be well insulated, care being taken to keep out mice and rats. The floor should be provided with a drain.

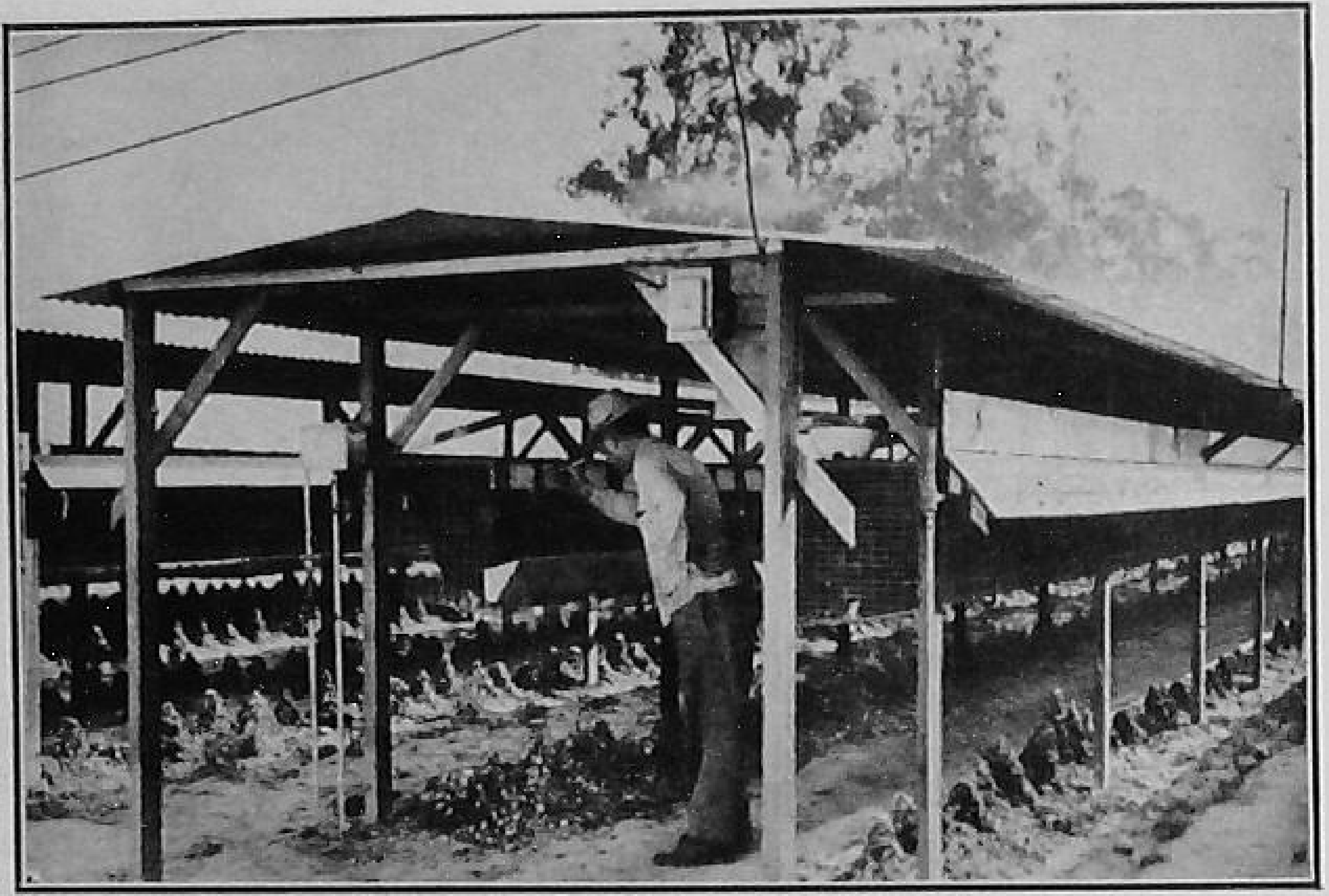


FIG. 141. Layers in cages on a California poultry plant. (*H. L. Belton and V. S. Asmundson, Calif. Agr. Exp. Sta.*, 1949.)

Temperature Requirements. In the southern sections of the United States it is probably not necessary to heat the laying-cage room during the winter months, but in the North some heat is apparently necessary for best results. An even temperature of about 45°F. is desirable, and in the case of a large room containing 1,000 or more layers a hot-air, forced-circulation heating system is preferred by many laying-cage operators.

Ventilation Requirements. The ventilation of the laying-cage room is a problem requiring a special ventilating system, if large numbers of birds are kept in batteries in a single room. In view of the cubic contents of most laying-cage rooms in relation to the number of birds involved, however, there is usually no trouble in supplying adequate quantities of fresh air or in removing carbon dioxide. In order to provide adequate ventilation, electrically operated fans are usually installed in the walls or in ventilating shafts through the roof.

Poultrymen who keep laying hens in cages should appreciate the fact that the ventilation system employed for the battery room should be correct in principle. Accurate knowledge of the size of ventilators required for a particular room is of the greatest importance. In experiments conducted in England it was found that the most satisfactory

returns from the birds were obtained when the air was changed eight times per hour. The cowls used on the outlets should operate independently of the direction of the wind.

The cubic contents of the room to be ventilated should be ascertained; multiplying this by 8 gives the amount of air to be introduced into the room and drawn off every hour. The correct type of cowl for the outlet should have a guaranteed rate of extraction per hour, so that the proper number of cowls can be easily determined according to the size of the battery room to be ventilated.

There should also be a proper balance between intakes and outlets in order to provide for balanced ventilation. The air introduced at the floor level must be entirely draftless. The air movements within a cage room full of laying hens should be tested by an anemometer in order to make sure that adequate ventilation may be provided.

Humidity Requirements. The health and egg production of the layers is influenced not only by the temperature and ventilation of the laying-cage room but also by the humidity of air in the room. On the other hand, supplying humidity is not a problem of great concern except in the case of large laying-cage plants, in which case a humidifier attached to the heating unit can be utilized to keep the relative humidity of the air in the room at about 50 per cent.

Building and Installation Service Available. The building of a proper type of laying-cage room and the proper installation of heating, ventilating, and humidifying units involves so many technical details that a properly qualified engineer should be consulted. A poultryman thinking of installing laying cages for the first time should give most careful consideration to the initial costs of the building and cages as well as to the costs of operating and maintaining the laying-cage system. Particular care should be taken to secure well-made cages which are durable, rust-proof, and well finished. The feeding and watering arrangements should be simple, and the system for removing the droppings should be efficient. Probably the best type of cleaning equipment is a heavy galvanized-iron trough over which a metal scraper is drawn.

Laying-cage Management Problems. Success with laying cages depends not only upon the proper kind of building and efficient cages but also upon the routine care that the birds receive. With certain types of cages two outstanding objections have materially lowered profits. The wastage of feed that occurs, regardless of whether mash or pellets are fed, and the number of eggs that are slightly cracked are factors with which most laying-cage operators have had to contend.

In order to secure profitable returns from layers kept in cages, it is necessary to have practically all the cages occupied throughout the year.

A relatively high precentage of the birds must be replaced every month. In order to provide replacements, it is necessary to raise a batch of pullets practically every month. Egg production must be maintained at a high level, and good egg prices must be secured to ensure profitable returns from the enterprise.

The feed and water troughs should be kept scrupulously clean at all times, and the cages should be thoroughly cleaned and disinfected at regular intervals. In order to control red mites, fumigating the laying cages may be necessary. The droppings should be removed daily, or strong odors are liable to permeate the atmosphere. The method of feeding, including the use of artificial lights, is discussed in subsequent chapters. The ultimate success achieved with laying cages depends largely upon the careful attention to many items of daily management, the details of which are much more exacting than in the case of laying stock kept in the ordinary type of laying house.

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CHAPTER 9

FEEDING PRINCIPLES

The primary function of poultry is to convert the nutrients contained in the cereal grains and other feedstuffs into eggs and meat for human consumption. That this be done as efficiently as possible is in the interests of every poultry producer.

Most flocks of growing chickens consume too much feed per pound of gain in weight, and most flocks of layers consume too much feed per dozen eggs produced. This may be due to the inferior breeding quality of the birds, faulty flock management, or feeding improperly balanced diets, or any two or all three of these factors. The problem of breeding for rapid growth and high egg production and the importance of good flock management have been discussed in previous chapters.

The primary objective in feeding poultry is to secure the most economical gains in weight during growth and fattening and the most economical production of eggs throughout the laying year. In order to secure the best results in feeding, certain basic principles must be kept in mind with respect to the kind and quantity of nutrients in various feedstuffs and the extent to which they are utilized efficiently by growning chickens and laying hens.

THE NUTRIENTS

The nutrients in feedstuffs are classified on the basis of their physical, chemical, and biological properties into the following six general groups: (1) water, (2) carbohydrates, (3) fats, (4) proteins, (5) minerals, and (6) vitamins. Among these six nutrients, water alone is a definite chemical compound; the other five classes of nutrients are classes or groups of compounds each of which, for the most part, serves a particular function in nutrition.

The body of the fowl and the egg are also composed of these same nutrients. Although there is some relationship between the occurrence of certain nutrients in feedstuffs and their use in building tissue in the fowl's body and in the formation of the egg, in most cases the fats, proteins, and carbobydrates in the feedstuffs are reduced to simpler substances in the digestive tract, absorbed and recombined in different forms in the tissues of the body and in eggs.

Water. Water, which is composed of the elements hydrogen and oxygen in the proportion of 2 to 1 (H_2O), not only accounts for approximately 56 to 78 per cent of the fowl's body and 66 per cent of the egg but ranks far above any other substance as regards rate of turnover in the body. Water facilitates cell reactions and is able to absorb the heat of these reactions with a minimum rise in temperature. The latent heat of vaporization that water possesses enables it to play an important role in regulating body temperature. Water serves an important role in lubricating the joints and acts as a water cushion for the nervous system. It serves to soften the feed, aids in the processes of the digestion and absorption of other nutrients, serves in transporting the end products of digestion from the digestive tract to various parts of the body, and assists in the elimination of waste products.

Carbohydrates. The carbohydrates, for the most part, do not occur as constituents of the animal body. Nevertheless, they form by far the largest share of the poultry diet for the simple reason that they constitute about three-fourths of the dry weight of plants and cereals. The plant, with the aid of its chlorophyll, utilizes the energy of the sun to build up carbohydrates, such as starches, sugars, and cellulose. The carbohydrates are composed of carbon, hydrogen, and oxygen, the hydrogen and oxygen nearly always being in the same ratio as in water. In the poultry diet the carbohydrates serve as a source of energy for the fowl's body and for the production of fat.

Starch is a common substance in all poultry diets, the starch of the corn kernel being a common source. In the fowl, glycogen, or animal starch, is stored in the liver and muscles. Sugars are also used in the diet, lactose, the sugar of milk, being a familiar example. Cellulose represents the crude fiber of the poultry diet but is not a good source of energy in poultry nutrition.

The nitrogen-free extract consists of the digestible carbohydrate portion of a feedstuff and includes the sugars, starches, and soluble portion of the more complex carbohydrates. The nitrogen-free extract represents the difference between the total weight of the feedstuff and the sum of the weights of the moisture, ash, fiber, fat, and crude protein.

Fats. The fat that is deposited under the skin, around the gizzard and intestines, and elsewhere in the body as well as in the yolk is derived largely from the starches and fats in the feed. Fats comprise the true fats and certain fatlike substances.

The true fats are composed of carbon, hydrogen, and oxygen but in different proportions from those in the carbohydrates, the proportion of oxygen in fats being much lower than in carbohydrates. Fats serve as sources of energy for the body, just as carbohydrates do, but since fats

contain relatively less oxygen they yield approximately 2.25 times as much energy as a similar quantity of carbohydrates.

Fats in plants are formed from carbohydrates and are present in certain quantities in all cereal grains but in smaller proportions than in the body of the fowl and the egg. The content of fat in live birds varies from about 17 to about 20 per cent, depending somewhat upon the age of the bird. The fat content of a fresh egg is about 10 per cent, mostly in the yolk, the fat content of which is over 33 per cent.

Ether extract, or crude fat, includes the true fats and all related plant and animal substances soluble in ether or other fat solvents. Ether extract, therefore, includes true fats, sterols, carotenes, chlorophyll, phospholipids, waxes, and essential oils, some of which are much more important in poultry nutrition than others. Sterols are alcohols, ergosterol being a plant sterol which performs the function of vitamin D upon being irradiated with ultraviolet rays, and cholesterol being an animal sterol present in the skin, fat, blood and upon being irradiated with ultraviolet rays also performs the function of vitamin D. Carotene is a plant pigment that is transformed into vitamin A in the fowl's body. Chlorophyll is the green-colored substance in green plants by means of which carbohydrates are formed in the leaves. Lecithin is a phospholipid present in the blood, liver, and the yolk of the egg.

Proteins. Since protein is one of the principal constituents of the organs, muscles, and other parts of the fowl's body, an adequate supply of protein should be available in the feeds in order that growth and tissue repair may proceed normally. Not only do plant proteins differ from each other, but they also differ from animal proteins. Moreover, each animal contains many proteins peculiar to the species to which the animal belongs. Proteins are complex substances containing the elements carbon, hydrogen, oxygen, and nitrogen; most proteins also contain sulfur, and a few of them contain iron and phosphorus. The outstanding characteristic of proteins is the presence of nitrogen, of which they contain approximately 16 per cent. Therefore, in calculating the amount of protein in any poultry feed, the amount of total nitrogen present is multiplied by 6.25, since $100 \div 16 = 6.25$. It should be observed, however, that it is not always true that all of the nitrogen is in protein form, nor do all proteins contain 16 per cent nitrogen.

Cereal grains and most other feedstuffs of plant origin contain relatively less protein than is contained in the body of the fowl and in the egg. Animal products, such as milk, fish meal, and meat scraps, are relatively rich in proteins and are usually used in balancing diets for poultry.

In chickens, the protein content varies from about 15 per cent early in life to about 25 per cent as the bird reaches maturity, but in fat hens

the protein content may be about 12 per cent or even less. The fresh egg contains about 12 per cent protein, and the dry matter of a fresh egg contains about 50 per cent protein. The dry matter of the yolk contains about 34 per cent protein, and the dry matter of the white or albumen contains about 94 per cent protein. The skin, feathers, muscles, and internal organs consist mostly of proteins.

Proteins in feedstuffs serve as an important source of nutrients for growth and repair of tissues as well as in the production of eggs. Practically all feedstuffs contain several different proteins. All proteins are made up of amino acids, at least 10 of which are considered to be essential

Fig. 142. This 4-weeks-old White Leghorn was fed a diet deficient in arginine and glycine, two amino acids necessary for proper feather development. (*G. M. Briggs, University of Maryland.*)

amino acids because they cannot be synthesized in the body of the chicken and must therefore be supplied in the diet. These 10 essential amino acids are: arginine, histidine, leucine, isoleucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Glycine and perhaps glutamic acid must also be provided in the diet for rapid growth. At least 11 other amino acids are known: alanine, aspartic acid, cystine, hydroxyglutamic acid, hydroxyproline, idiogorgoic acid, norleucine, proline, serine, thyroxine, and tyrosine. Among these 11 amino acids, the following are required in the diet under certain conditions: cystine, proline, and tyrosine. With respect to the requirements of the growing chicken for the various amino acids, only arginine, cystine, glycine, lysine, methionine, and tryptophan need particular attention in practical rations.

The particular amino acids contained in the protein of a feedstuff determine to a considerable extent its nutritive value in poultry nutrition. Although some proteins may lack one or more of the essential amino

acids, a combination of these different proteins may produce satisfactory growth and egg production because of the supplementary effects of the various amino acids provided by these different proteins.

In developing formulas for poultry diets, it is advisable to use feedstuffs that provide adequate amounts of the essential amino acids and a total protein level that will promote rapid growth and maintain a high level of egg production. Although it has been customary to speak of essential and nonessential amino acids, it is interesting to note that the deficiency of a nonessential amino acid in a diet may actually increase the requirement of one or more of the essential amino acids.

Minerals. The need of minerals in the diet is made clear when the mineral content of the fowl and the egg is taken into consideration, approximately 3 to 4 per cent of the fowl's body and about 10 per cent of the egg being composed of mineral matter. The shell constitutes approximately 10 per cent of the total weight of the egg and is composed almost entirely of calcium carbonate. A large number of mineral elements occur in combination with each other and in combination with the organic constituents of the fowl's body; the bones and eggshell especially are rich in minerals or ash.

Up to the present, the following minerals have been found to perform essential functions in the body: calcium, phosphorus, sodium, magnesium, chlorine, potassium, iron, sulfur, iodine, manganese, copper, zinc, and fluorine, which is highly toxic in large amounts. Other mineral elements, such as barium, strontium, and vanadium, have been found to be more concentrated in the blood of the chicken and in the egg than in the feed, and it may be that these mineral elements are of considerable physiological importance. Calcium, in the form of a carbonate, constitutes most of the eggshell. Calcium, sodium, and potassium salts are essential for muscular activity; and calcium, phosphorus, and magnesium, in the form of inorganic salts, are important constituents of bone. The egg contains appreciable amounts of sulfur and phosphorus; and the blood contains iron, copper, and chlorine. Manganese is necessary for proper bone formation, and zinc is necessary for optimum growth. Iodine is contained in extremely small amounts in the body but is necessary in feed for the proper functioning of the thyroid gland.

Aside from providing mineral constituents for the fowl's body, minerals in the diet are of great importance in enabling fowls to utilize other nutrients to best advantage. At the same time, most of the minerals are required in relatively small amounts.

The fact that a given mineral element is essential in the diet is demonstrated by the structural or functional injury occurring in birds given diets abnormally low in that particular element. Fortunately, most of

the essential mineral elements are contained in sufficient quantities in the normal diet of the chicken so that little concern need be given regarding supplying additional amounts. Sodium, chlorine, and manganese are sometimes needed in addition to minerals furnished in common farm feeds. Sodium and chlorine are supplied by feeding common salt. Manganese is readily supplied as the sulfate or dioxide. Of particular concern in poultry nutrition, however, are the absolute and relative amounts of calcium and phosphorus in the diet. Vitamin D must be

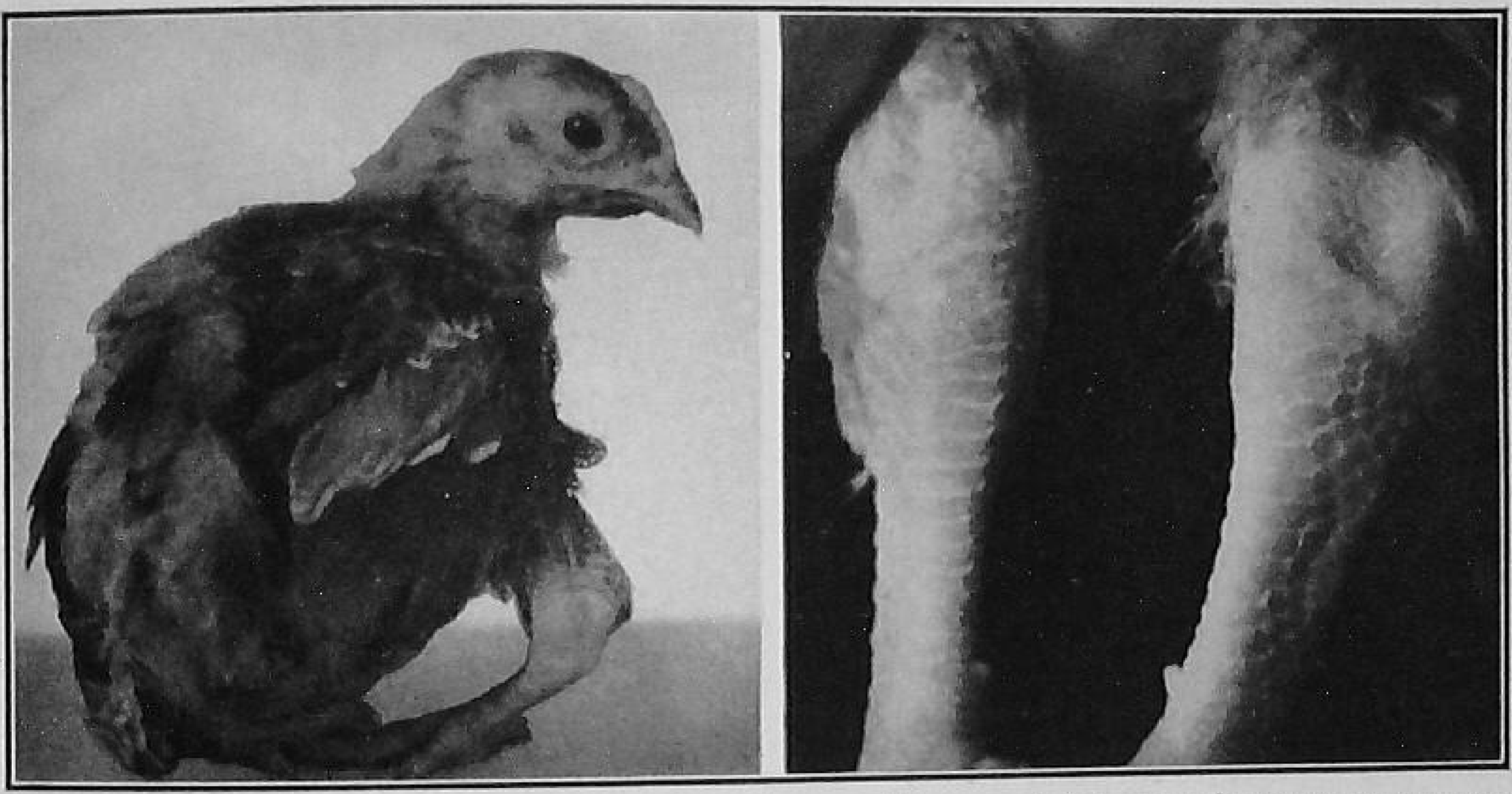


FIG. 143. Left, perosis or slipped tendon, due usually to a deficiency of manganese or an excess of minerals in the diet. A deficiency of either choline or biotin may also result in perosis. Right, a close-up view showing characteristic swelling of the hock joint and the Achilles tendon that has slipped from its normal position. (*University of Maryland.*)

supplied in adequate amounts for the utilization of calcium and phosphorus. Calcium is furnished in the form of limestone, oystershells, or clamshells. Phorphorus may be supplied by adding dicalcium phosphate or defluorinated rock phosphate to the diet or in the form of steamed bone meal or in the bone portion of meat scrap and fish meal.

Vitamins. Rations containing the proper amounts of water, proteins, carbohydrates, fats, and minerals sometimes give unsatisfactory results in growth, bone formation, and egg production. Investigational work has demonstrated that in many cases the unsatisfactory results are due to inadequate amounts of certain vitamins. These substances are interesting from the standpoint that although a marked deficiency in the diet of almost any one of them may cause a serious nutritional disorder, relatively small amounts are necessary to prevent the disorders. They are very necessary for normal growth, reproduction, the maintenance of health, and some of them affect the growth and pigmentation of feathers.

The vitamins are of two general kinds, (1) fat-soluble vitamins, such as A, D, E, and K, and (2) water-soluble vitamins, including B_{12}, choline, folic acid, inositol, nicotinic acid, pantothenic acid, pyridoxine, riboflavin, and thiamine, all of which belong to the B-vitamin complex.

Vitamin A. This is a fat-soluble vitamin which needs special attention in feeding poultry. Vitamin A is formed in the bird's body from carotene

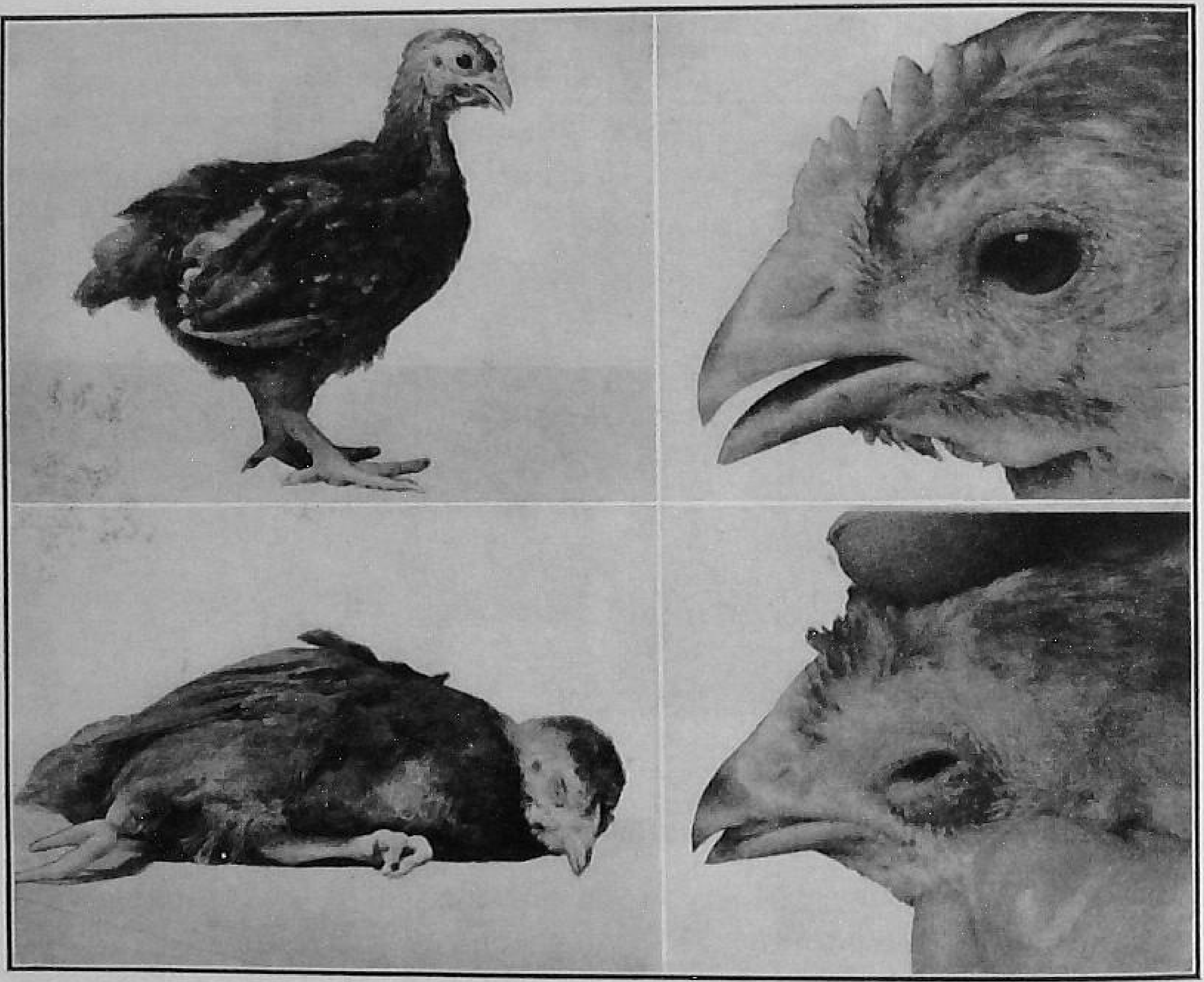


Fig. 144. Top left, normal chicken fed a diet not deficient in vitamin A. Top right, a close-up view of the eye of the chicken shown at top left. Bottom left, chicken fed a diet deficient in vitamin A. Bottom right, a close-up view of the eye of the chicken shown at bottom left: note the swollen condition of the eye. Other symptoms of vitamin-A deficiency are poor growth, general weakness, staggering gait, and ruffled feathers. (*G. M. Briggs, University of Maryland.*)

and cryptoxanthin contained in certain feedstuffs. In other words, the pigments carotene and cryptoxanthin are precursors of vitamin A. Carotene occurs in green plants and yellow corn. The livers of animals serve as storehouses of vitamin A. Because of this, the oils obtained from the livers of cod, bass, eels, and halibut are among the richest natural sources of true vitamin A.

Besides being necessary for many of the normal life processes, vitamin A is particularly important in maintaining healthy epithelia in the eyes, the respiratory and digestive tracts, and other parts of the body. In

growing chickens fed a diet markedly deficient in vitamin A, the symptoms of deficiency often begin to show in about 3 weeks. Loss of appetite, ruffled feathers, and general unthriftiness are characteristic symptoms. In advanced cases, the margins of the eyelids become granular, and pathological lesions develop in the mucous membranes of the mouth, pharynx, and the respiratory tract.

If infection sets in, a viscous fluid produced may cause the eyelids to stick together and sometimes a white film gathers over the center of the eyeball. In this case the disease is known as "xerophthalmia."

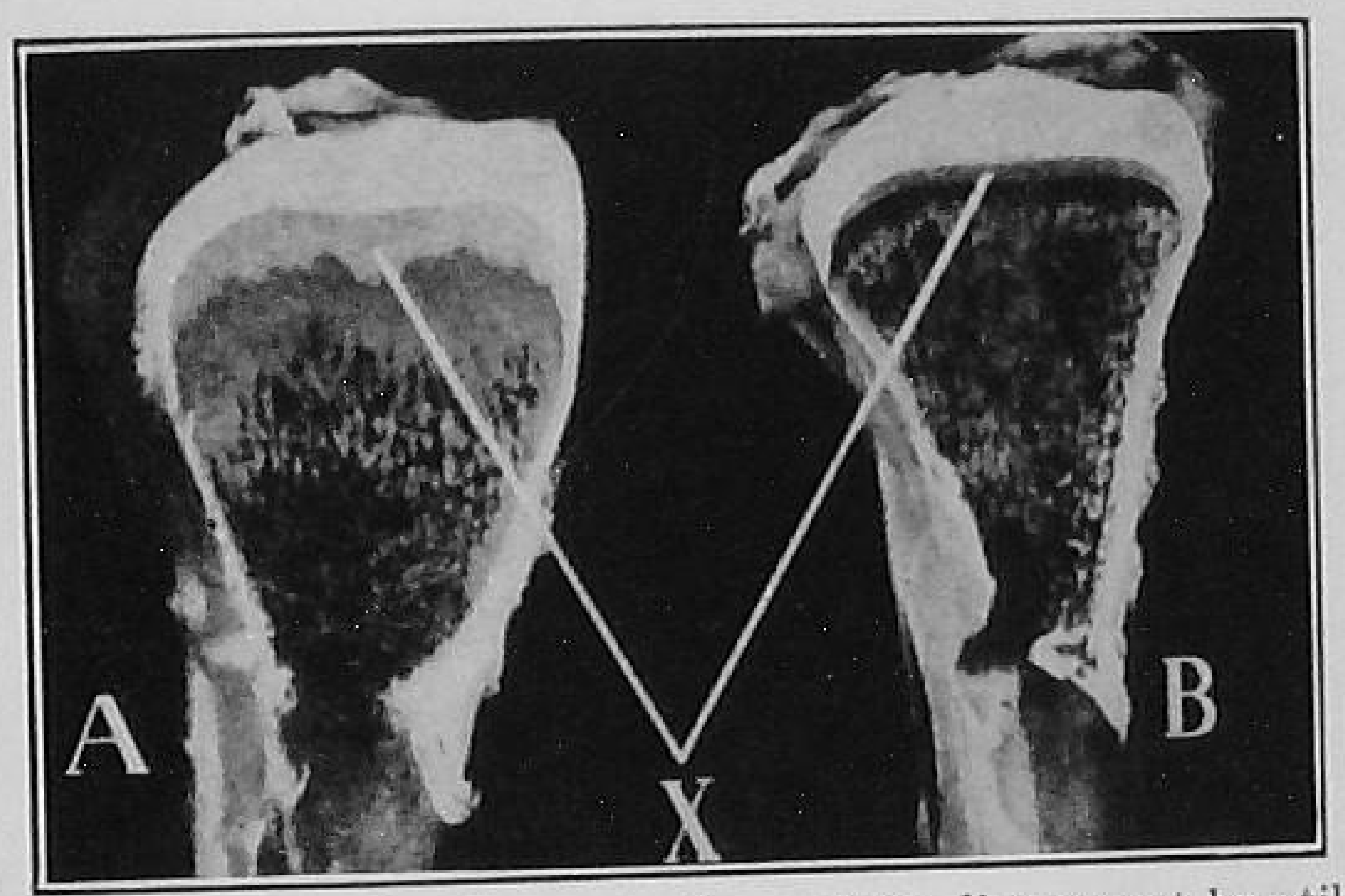


Fig. 145. The calcium and phosphorus portions of the diet cannot be utilized efficiently in bone formation if there is a deficiency of vitamin D in the diet, the result being a bone disease called "rickets." This illustration shows the difference in the calcification of the leg bones of chickens without and with a sufficient supply of vitamin D in the diet. In (*A*) is shown the leg bone of a chicken whose diet lacked sufficient vitamin D to promote proper calcification. In (*B*) is shown the leg bone of a chicken fed the same diet fortified with vitamin D. At *X* note the difference in the extent of the uncalcified areas. (*F. E. Booth Company, Inc.*)

When laying hens are fed diets deficient in vitamin A, the hatchability of the eggs is liable to be reduced, and in severe cases of the deficiency egg production may cease.

Since carotene and vitamin A are gradually destroyed when exposed to air, especially in hot weather, special precautions are sometimes necessary to ensure an adequate supply of vitamin A under these conditions.

An excess of vitamin A in the diet has a depressing effect on the functioning of the thyroid gland.

Ascorbic Acid (Vitamin C). A deficiency of ascorbic acid causes scurvy in some animals, including man, but chickens are not affected because they synthesize it in their own bodies.

Vitamin D. There are several forms of vitamin D, vitamin D_3 being the form which is most effective for chickens. This fat-soluble vitamin is relatively more stable than vitamin A.

Vitamin D is necessary for the deposition of calcium and phosphorus

in the bones of the body. It prevents rickets, a condition in growing chickens in which there is lameness and an enlargement of the hock joint accompanied by an unsteady gait. In laying hens, vitamin-D deficiency results in the production of thin-shelled eggs and finally in cessation of egg production. Hatchability is greatly reduced.

Irradiation with sunlight (not through glass) or ultraviolet light induces certain compounds of plant and animal origin to acquire vitamin-D properties. Cholesterol, a sterol in the skin of the chicken is activated to form vitamin D_3, the form that is abundant in fish oils. Ergosterol, a

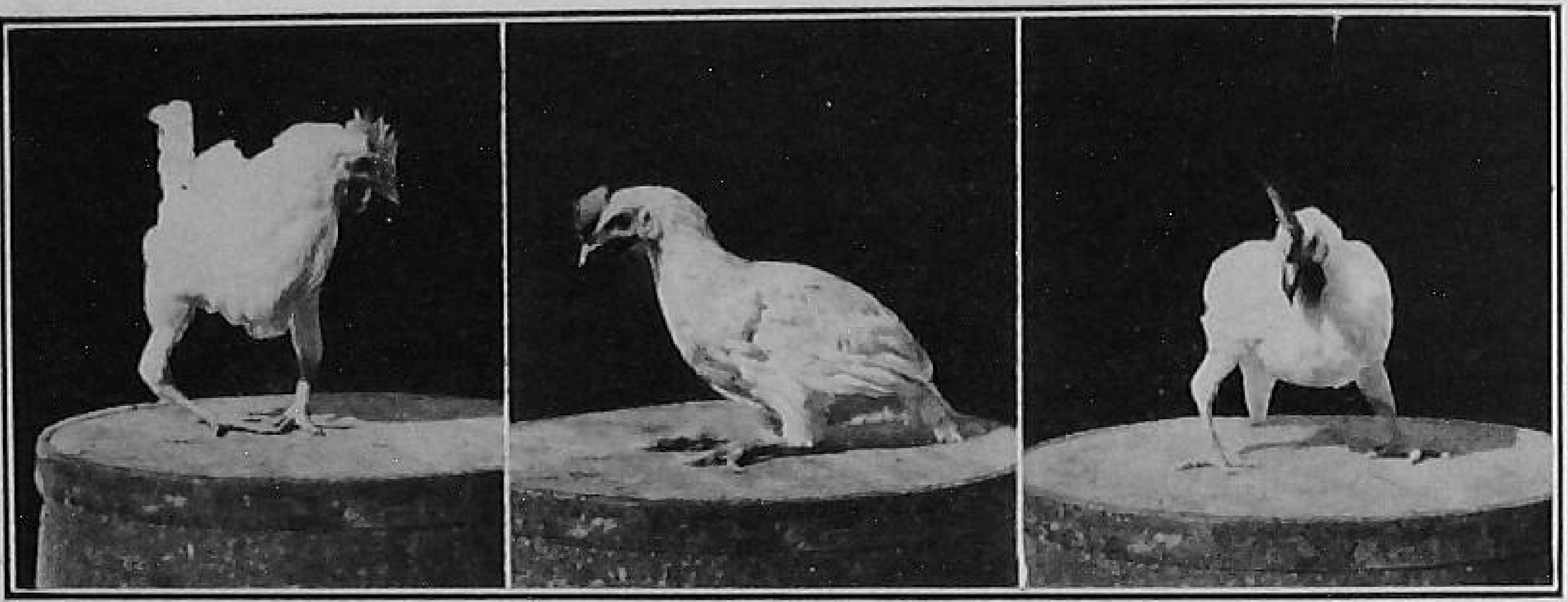


FIG. 146. Typical cases of rickets. (*U.S. Dept. Agr.*)

sterol in plants, upon irradiation by means of ultraviolet light, becomes vitamin D_2 which is of little value to poultry. Cod-liver oil is several times more effective in preventing rickets in chickens than is irradiated ergosterol. Irradiated cholesterol is as effective as cod-liver oil in preventing rickets in growing chickens.

Access to sunlight is highly desirable for breeding stock, growing chickens, and laying hens. In most parts of the country during the winter months, diets for growing chickens and adult birds should be supplemented with vitamin D_3. The same is true of all birds kept in strict confinement.

Fortified fish oils and irradiated animal sterols are the most potent sources of vitamin D_3.

Vitamin E. This fat-soluble vitamin, known chemically as "alpha-tocopherol," is of value in preserving the health of the reproductive organs and brain tissue. In growing chickens fed a diet devoid of vitamin E, a condition develops known as "crazy-chick disease" or nutritional "encephalomalacia." A condition often develops known as "edema," which is characterized by a puffy swelling resulting from the accumulation of serous fluid in the subcutaneous tissue. Males fed diets markedly deficient in vitamin E give poor fertility. Females fed diets very low in vitamin E produce eggs low in hatchability.

Only when feed becomes rancid is the supply of vitamin E of any concern in feeding practice.

Riboflavin. This water-soluble vitamin was originally known as "vitamin B_2" or "vitamin G," but is chemically known as "riboflavin." It is necessary for growth, often being referred to as the "growth vitamin." It is stored in the white of the egg and in that way improves hatchability. It is necessary for the health of the skin and for the

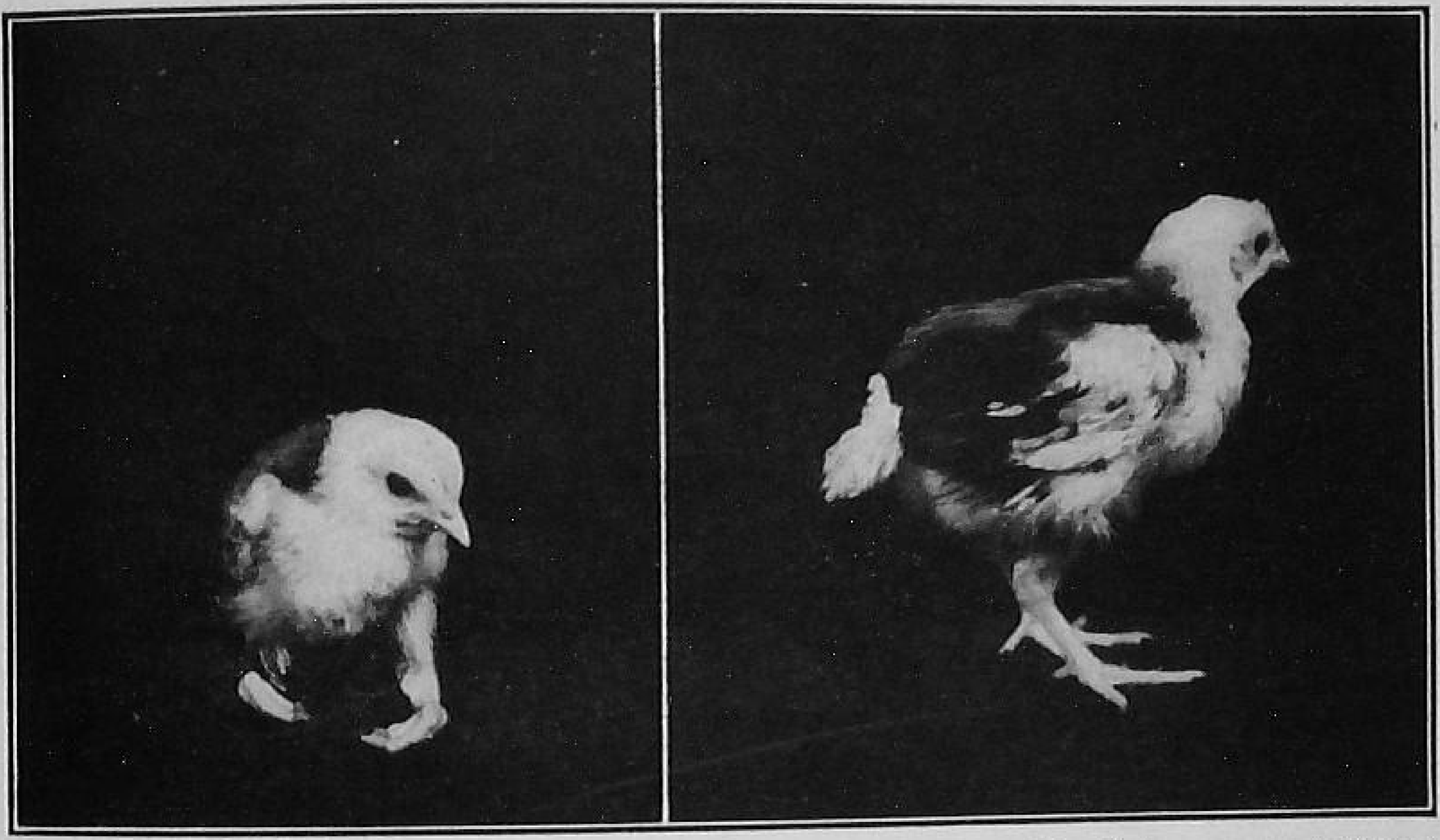


FIG. 147. Left, riboflavin-deficiency symptoms in a 16-day-old chicken: note deficient feathering and "curled-toe" paralysis. Right, same chicken, 4 days later, completely recovered after being treated with crystalline riboflavin. (*A. G. Hogan, University of Missouri.*)

prevention of curled-toe paralysis of the legs. The riboflavin requirement for hatchability is higher than for egg production and the maintenance of health. Excessive embryo mortality during the second week of incubation is an indication of riboflavin deficiency in the diet of the breeding stock.

Liver, yeast, alfalfa meal, green grass, and milk products are among the chief sources of riboflavin.

Vitamin K. This fat-soluble vitamin is known as the "antihemorrhagic vitamin," since it prevents death from hemorrhage. The function of vitamin K is to aid in the formation of prothrombin, a substance present in normal blood which is required for the production of thrombin itself before fibrin can be formed and the blood can clot. In the absence of vitamin K, a condition occurs in which blood-clotting time may be greatly and even indefinitely prolonged.

In growing chickens fed a diet deficient in vitamin K, death from bleeding is liable to occur if blood vessels are severed, as in wing-banding.

Mature birds are not likely to suffer from a deficiency of vitamin K, since it is synthesized in the intestinal tract to some extent. However, hens fed a diet deficient in vitamin K produce eggs low in the vitamin, and chicks hatched from these eggs are susceptible to excessive bleeding because of greatly prolonged blood-clotting time.

The chief sources of vitamin K are alfalfa meal, green grass, fish meal, and meat scrap.

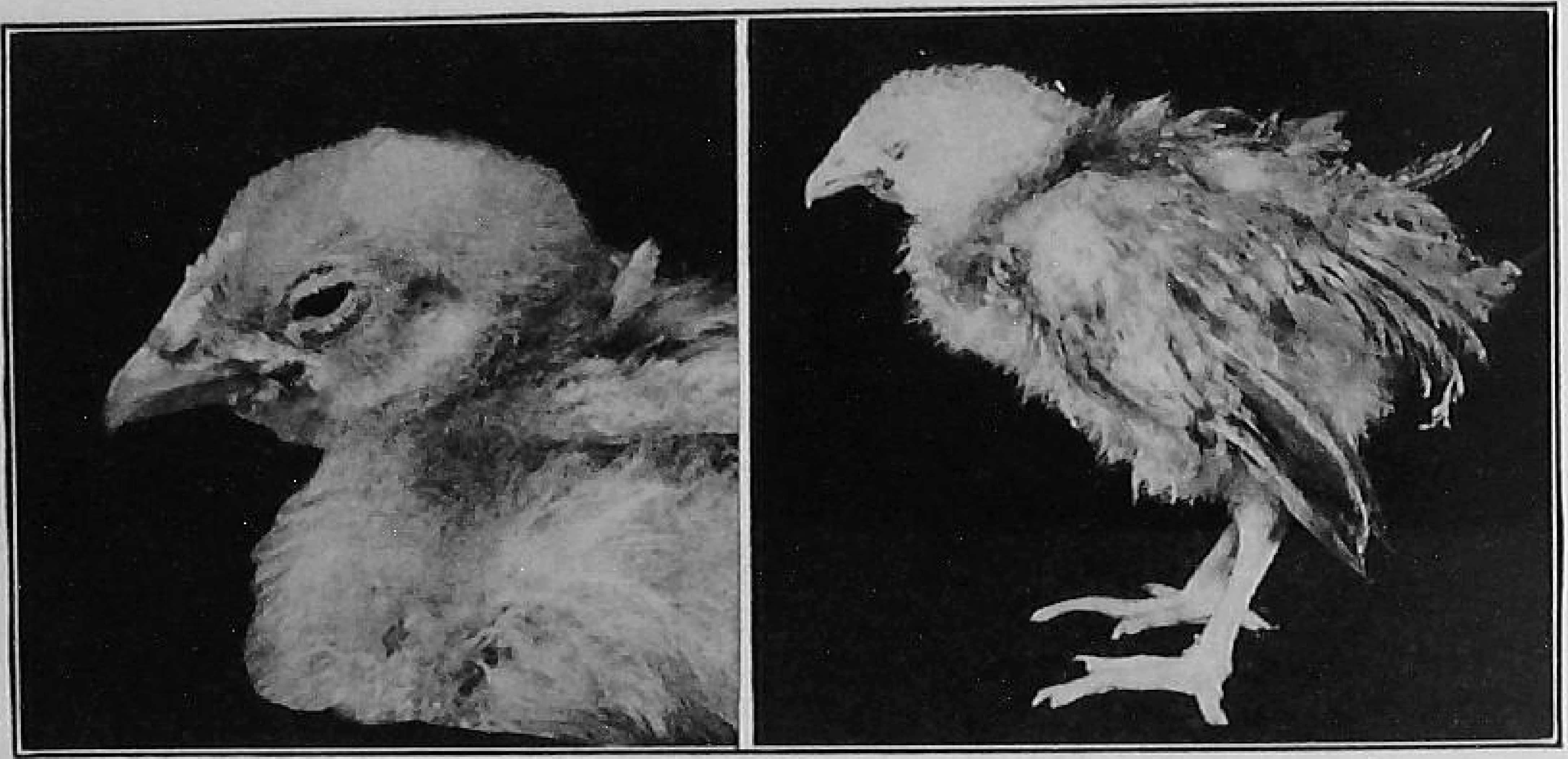


FIG. 148. Left, pantothenic-acid deficiency in a 4-weeks-old New Hampshire chicken: note crusty scabs at corners of mouth and eyelids inclined to stick together. (*G. M. Briggs, University of Maryland.*) Right, pantothenic-acid deficiency showing closed eyelids and ragged feathers. (*T. H. Jukes, Lederle Laboratories.*)

Pantothenic Acid. This water-soluble vitamin is also known as the "antidermatitis vitamin." A marked deficiency of pantothenic acid in the diet of growing chickens results in retarded growth and extremely ragged feathering. In about 2 weeks, the eyelids become granular and stick together, scabby lesions appear at the corners of the mouth and around the vent. In severe cases, dermatitis of the feet develops in which the skin on the bottoms of the feet becomes thickened and covered with scabby lesions. Panthenol may be used as a substitute for pantothenic acid. Breeding stock fed a diet markedly deficient in pantothenic acid produce eggs with relatively low hatchability.

Liver, yeast, alfalfa meal, green grass, milk products, peanut meal, and corn distillers' solubles are among the best sources of pantothenic acid.

Pyridoxine (*Vitamin B_6*). This water-soluble vitamin of the B-complex group is necessary for the maintenance of appetite and growth and the prevention of a certain type of convulsions. In growing chickens fed a diet deficient in pyridoxine, growth is retarded and the chickens run about aimlessly, show jerky movements, and finally go into convul-

sions and die. In breeding stock, loss of appetite is followed by loss of weight, a marked decrease in egg production, and lowered hatchability.

Under normal circumstances, a deficiency of pyridoxine is not likely to occur since it is contained in grains, wheat and rice by-products, liver, yeast, milk products, fish meal, and meat scrap.

Thiamine (*Vitamin* B_1). A diet deficient in this water-soluble vitamin produces nervous disorders in growing chickens and adult birds, hence the name of the disorder is known as "polyneuritis." In acute cases,

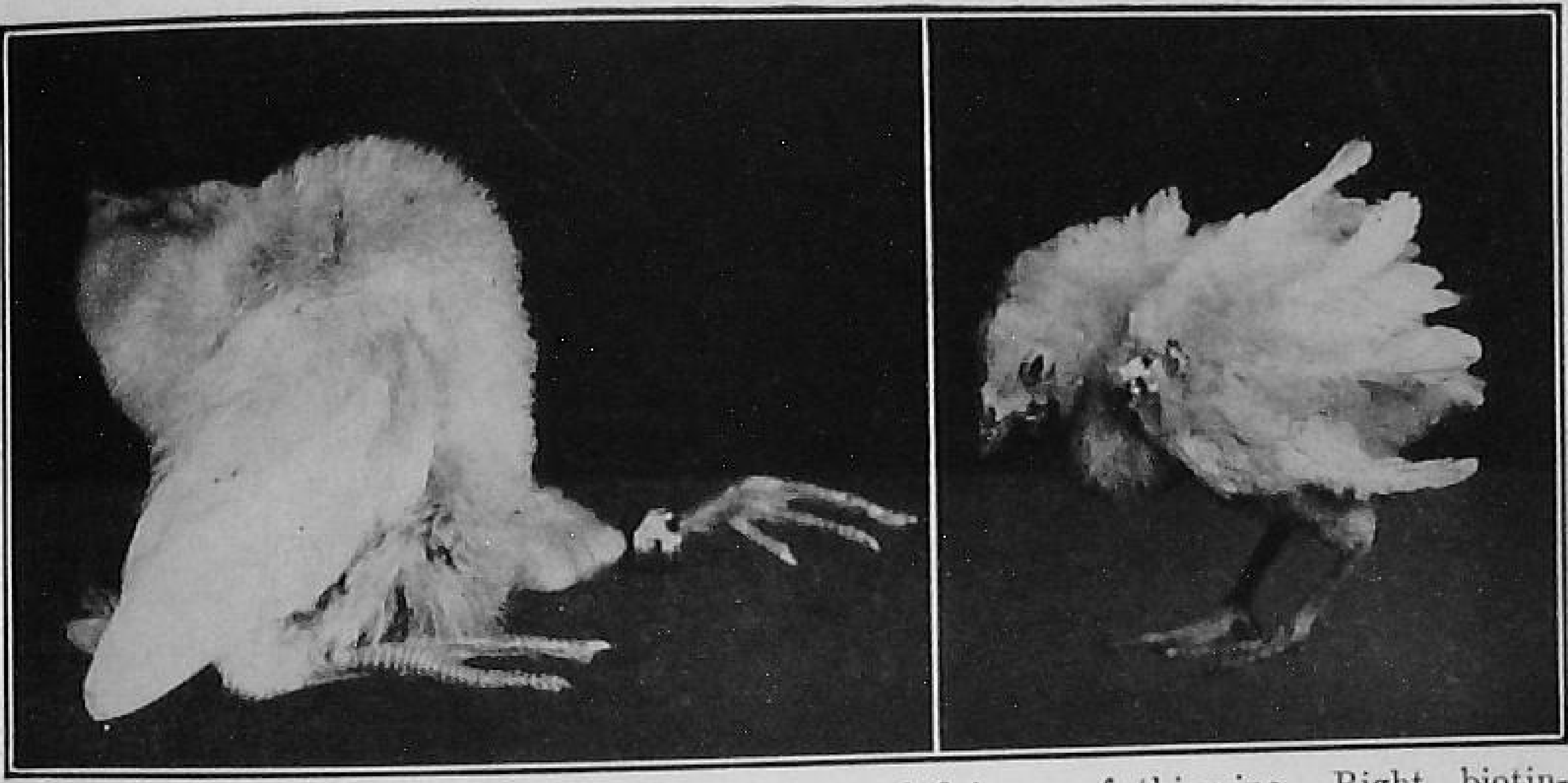


Fig. 149. Left, head retraction caused by a deficiency of thiamine. Right, biotin-deficiency symptoms, showing lesions at the corner of the mouth. Bottoms of feet also often have severe lesions. (*Cornell Univ. Poul. Dept.*)

the head may be drawn over the back. Since thiamine is present in abundance in cereal grains, green leafy feedstuffs, and skim milk, there is small chance of most rations being deficient.

Biotin. This is a water-soluble vitamin necessary for normal growth and good hatchability and is involved in the prevention of perosis and a dermatitis condition similar to that resulting from pantothenic-acid deficiency. In growing chickens, biotin deficiency gives rise to lesions on the skin on the bottoms of the feet in about 3 weeks. Hemorrhagic cracks appear, and the toes may become necrotic and slough off. Lesions may also appear on the mandibles. In laying hens, biotin deficiency does not give rise to dermatitis or affect egg production, but hatchability is reduced. This indicates that the biotin requirement for the production of hatching eggs is considerably higher than that for market-egg production.

It is interesting to note that avidin, one of the proteins in egg white, gives rise to biotin deficiency when chicks are fed raw egg white.

Biotin is contained in cereal grains, liver, yeast, alfalfa meal, green grass, milk products, cane molasses, and soybean meal.

Choline. This water-soluble vitamin is necessary for normal growth, proper bone development, and normal egg production. Growing chickens fed a diet deficient in choline develop slipped tendon or perosis, even though the diet was otherwise complete. In laying hens fed diets deficient in choline, egg production is lowered and there is increased embryonic mortality.

Choline is rather widely distributed in feedstuffs, being present in wheat bran and middlings, liver meal, meat scraps, fish meal, milk products, and soybean meal.

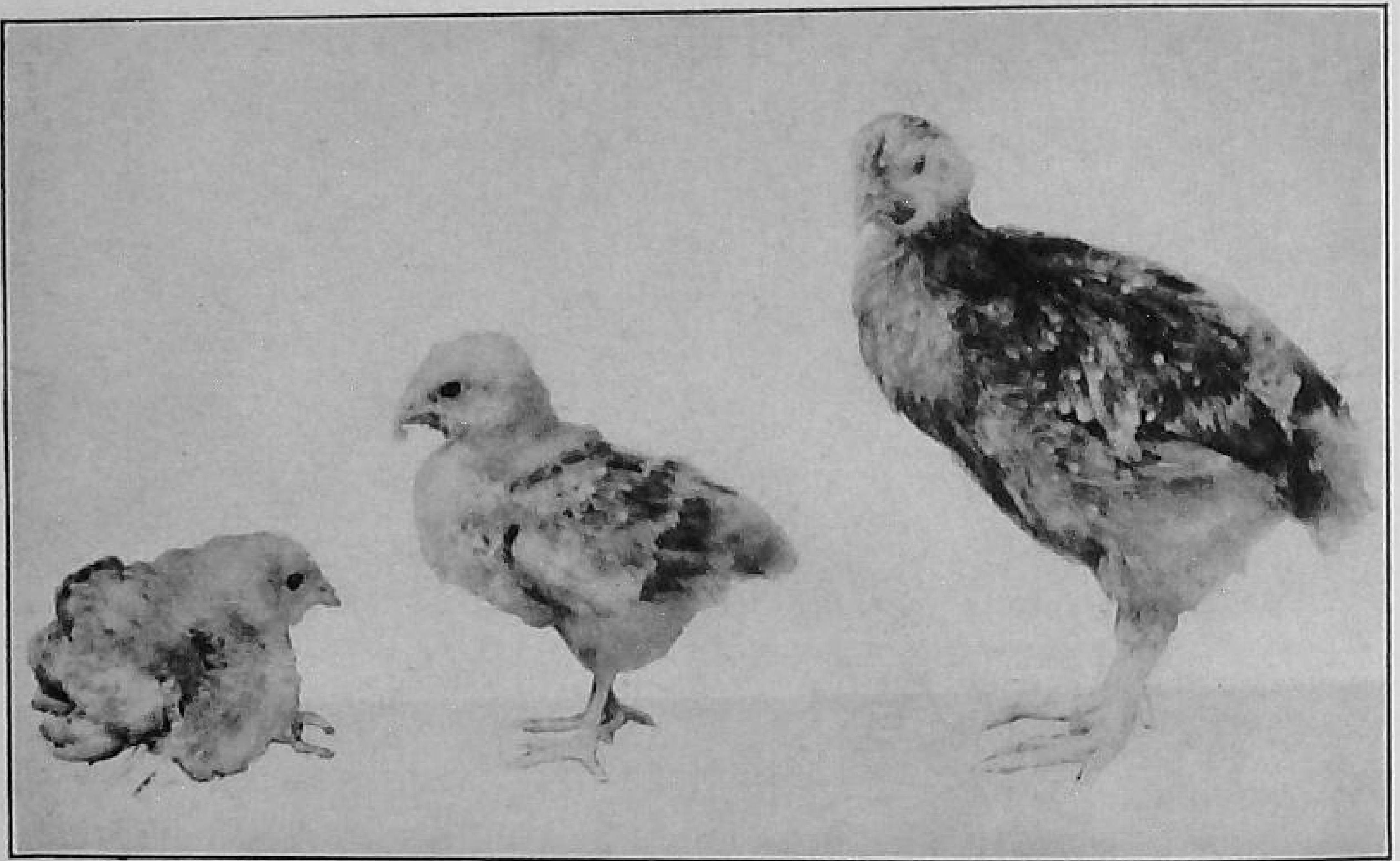


FIG. 150. All three chickens are 4 weeks old. The one at the left was fed a diet deficient in choline, which is necessary for proper growth and the prevention of perosis. The chicken in the center was fed a diet deficient in nicotinic acid. The chicken at the right was fed a diet containing sufficient quantities of choline and nicotinic acid and grew normally. (*G. M. Briggs, University of Maryland.*)

Nicotinic Acid (Niacin). This water-soluble vitamin is necessary for growth and normal feather development. Growing chickens fed a diet deficient in nicotinic acid develop a blacktongue condition which is characterized by inflammation of the tongue and cavity of the mouth. Feed consumption decreases, growth is retarded, there is poor feather development, and perosis develops. The nicotinic-acid requirement of growing chickens is influenced by the character of the protein in the diet.

The chief sources of nicotinic acid are liver, yeast, barley, wheat bran and middlings, peanut meal, corn-gluten feed, and corn distillers' solubles.

Folic Acid. This member of the vitamin-B complex is needed by young chickens for growth, feather pigmentation, proper feather development,

and the formation of hemoglobin. Folic acid is needed by breeding hens for the production of eggs that hatch well and for normal endocrine function. Folic acid is known chemically as "pteroylglutamic acid."

Yeast and liver meals are excellent sources of folic acid; alfalfa meal of high quality is a good source; soybean-oil meal is a fairly good source; all grains, fish meal, and meat scraps are poor sources of this vitamin.

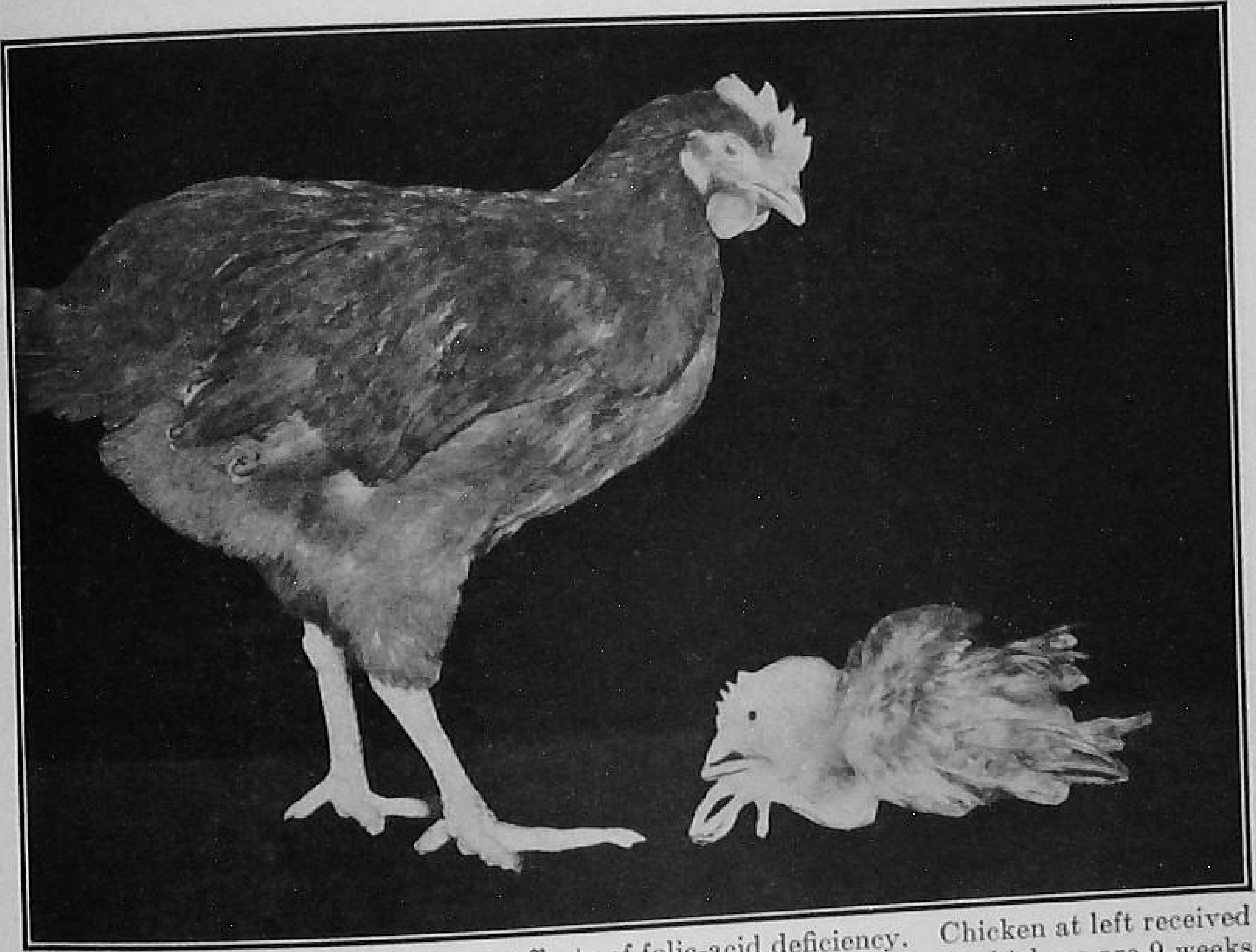


FIG. 151. Chicken at right shows effects of folic-acid deficiency. Chicken at left received the same diet plus an adequate amount of folic acid. Both of these chickens are 9 weeks old: the one at the left weighed 1,245 g., and the one at the right weighed 177 g. Folic-acid deficiency resulted in anemia, faulty feather growth, depigmentation of feathers, deformed hocks, and very slow body growth. (*T. H. Jukes, Lederle Laboratories.*)

Vitamin B_{12}. This antipernicious anemia factor in humans has been found to be of importance in the nutrition of growing chickens and for good hatchability of eggs. Growing chickens fed diets deficient in vitamin B_{12} are greatly retarded in growth, have poor feathering, and exhibit an unthrifty appearance. Vitamin B_{12} is contained in fish meal, meat scraps, liver meal, and other animal-protein concentrates, as well as in cow and chicken manure. Vitamin B_{12} concentrates are available for use in feeding poultry.

It is interesting to note that the practice of using built-up litter in brooder and laying houses has a nutritional advantage. The molds that develop in the litter soon die, and they are followed by yeast organisms,

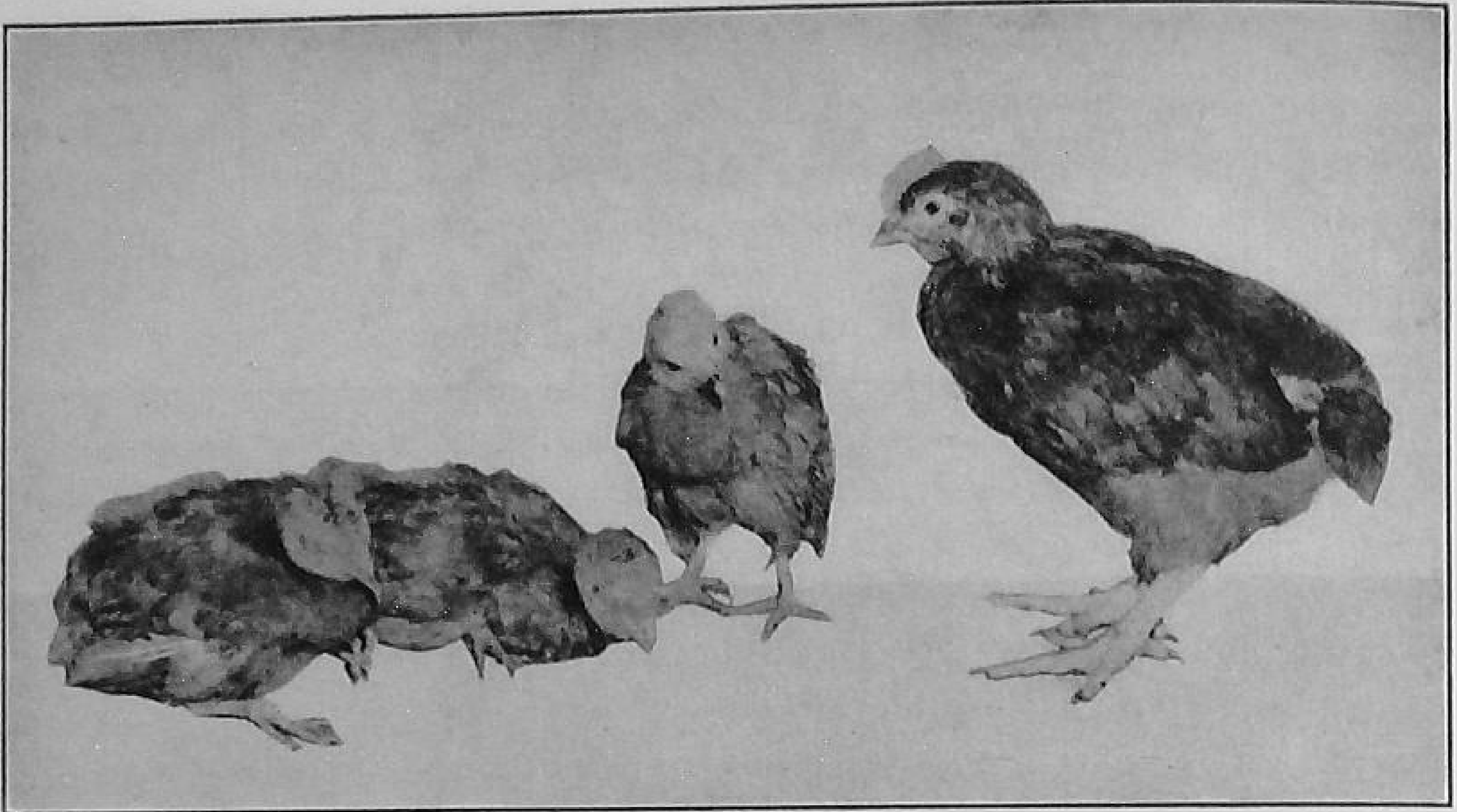


Fig. 152. These 5-weeks-old New Hampshires were fed the same vitamin-B_{12}-deficient diet, except that the one at the right was given supplementary vitamin B_{12} beginning at 2 weeks of age. Note the small size, poor feathering, and general unthrifty appearance of the three chickens fed a diet deficient in vitamin B_{12}. (*G. F. Combs, University of Maryland.*)

which in turn are followed by bacteria, some of which are concerned with the production of vitamin B_{12}.

Unidentified Vitamin. At least one unidentified vitamin required for growth in chickens has been found to be present in dried whey, liver, yeast, and fish meal.

Other Organic Factors. The following factors have been reported to be necessary for chickens: pyracin, inositol, glucoronic acid, and an antigizzard erosion factor.

Antibiotics. Certain antibiotics, such as aureomycin, penicillin, streptomycin, and terramycin, when added in relatively minute amounts to diets of young chickens, stimulate growth.

THE DIGESTION OF NUTRIENTS

Since most of the nutrients in feeds are not absorbed by the fowl's body in the form in which they occur in feeds, it is obvious that these nutrients must be "broken down" before they can be converted into the nutrients found in body tissues and secretions of the body. The process of digestion includes all the changes that take place in the feed from the time it is consumed until the nutrients are absorbed.

Feed Passage through Digestive System. Feed picked up is swallowed with the assistance of the tongue and is forced through the digestive tract by means of muscles in the walls of the tract. If the bird has had no feed for several hours, the first few mouthfuls swallowed pass directly into the empty gizzard. In the case of birds that have been feeding

regularly, however, a fresh mouthful of feed when swallowed passes down the gullet and into the crop, which continues to receive feed as long as the gizzard is full or partially full. Saliva, swallowed with the feed, and liquid secretions of the lining of the inner crop wall soften the feed while it is in the crop. Small quantities of feed take relatively a longer time to leave the crop than larger quantities. After about 4 hr., approximately 75 per cent of the grain intake is still in the crop but after about 24 hr. approximately 5 per cent is still in the crop.

Upon reaching the gizzard, the feed is ground into a fine mass by the rhythmic contractions of the gizzard, the pressure in grinding being very great. After the gizzard has ground the feed completely, it passes into the small intestine, where it is thoroughly mixed and brought into intimate contact with the intestinal wall.

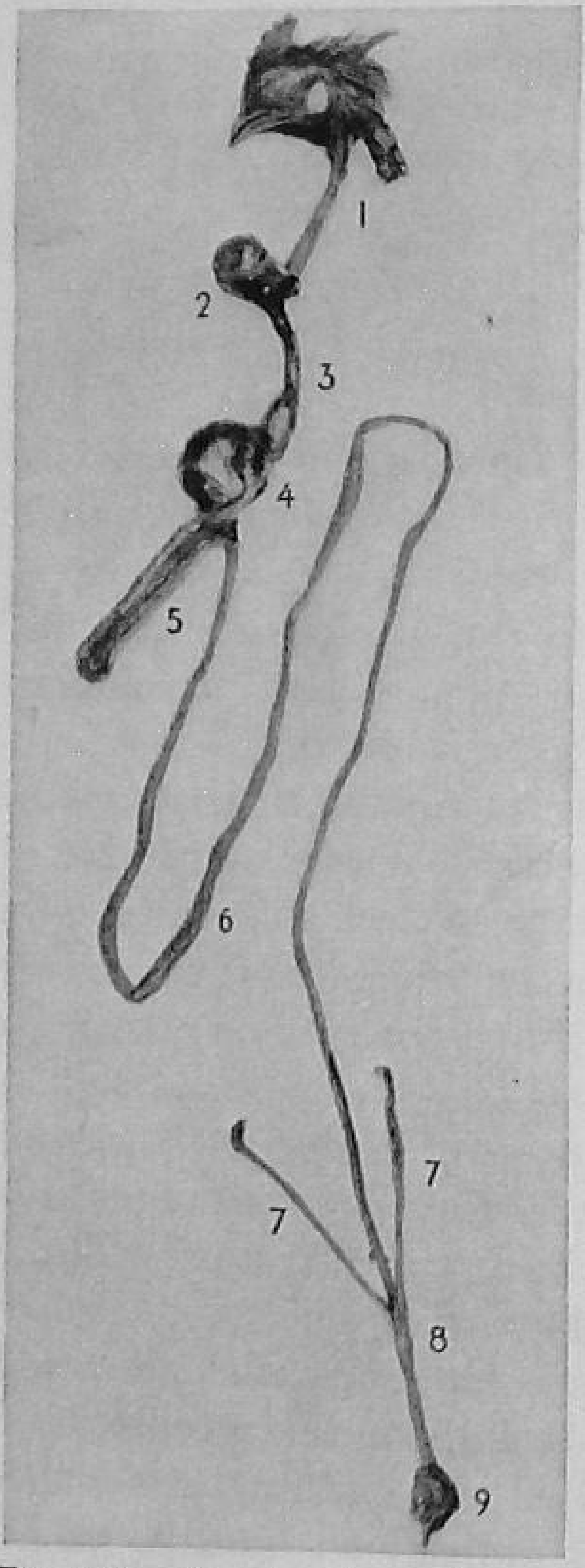
The feed mass passes from the small into the large intestine at the juncture of which the caeca, two blind pouches about 5 in. in length, open into the intestinal tract. The caeca rhythmically expand and contract and thus receive and reject the fluid contents of the intestine. The fluidlike feed mass passes along the large intestine until it accumulates at the cloaca, where portions are expelled at intervals.

From the time that feed is picked up by the laying bird approximately 2½ hr. are required for the feed mass to reach the cloaca. The rate of the passage of feed through the digestive tract of the adult hen not in laying condition is considerably slower than in the hen in laying condition, being about 8 hr. In the case of the broody hen the rate of passage is about 12 hr.

The Process of Digestion. During the process of digestion the carbohydrates, fats, and proteins are broken down by the secretions of various glands that are present in different parts of the digestive system. These glands secrete ferments or enzymes, which have the remarkable ability of bringing about changes in other organic compounds without being changed themselves. Their function is to attack the nutrients contained in the feed in order that they may be converted into end products which can be taken up by the innumerable small projections, called "villi," that line the intestinal tract and thus be absorbed. In other words, the starches and sugars comprising the carbohydrates, the fats, and the proteins are "broken down" into simpler compounds which can be absorbed by the body.

The enzymes which attack the starches are ptyalin and amylopsin. The enzymes which attack the sugars are lactase, maltase, and sucrase. The fats are acted upon by pancreatic lipase. The proteins are acted upon by pepsin, trypsin, and erepsin. The part of the digestive tract where these enzymes function is indicated in Fig. 153.

The mouth contains many salivary glands which secrete a starch-splitting enzyme called "ptyalin," converting starch in the feed into an end product called "maltose." There are no glands in the crop, which serves largely as a storage sac, but it is in the crop that the ptyalin acts as well as certain enzymes contained in the feed, where it takes on an acid



1. *Gullet.*
   Ptyalin in salivary secretions converts starch into maltose.

2. *Crop.*
   Lactase converts lactose into glucose and galactose.

3. *Proventriculus.*
   Pepsin in gastric juice converts proteins into proteoses and peptones.

4. *Gizzard.*

5. *Pancreas*, between folds of duodenum.
   Amylopsin in pancreatic juice converts starch into maltose.
   Pancreatic lipase in pancreatic juice converts fats into glycerols and fatty acids.
   Trypsin in pancreatic juice converts proteins into proteoses, the latter into peptones and polypeptids, both of which are converted into amino-acids.

6. *Small Intestine.*
   Maltase in intestinal juice converts maltose into glucose.
   Sucrase in intestinal juice converts sucrose into glucose and fructose.
   Erepsin in intestinal juice converts peptones into amino-acids.

7. *Caeca.*

8. *Large Intestine.*

9. *Cloaca.*

FIG. 153. Showing the regions of the digestive tract in which the various digestive processes take place. (*Photograph by A. R. Winter.*)

reaction due to the presence of lactic acid. While the feed is in the proventriculus, it is mixed with gastric juice containing hydrochloric acid and an enzyme called "pepsin," which reduces the protein in the feed into peptones. The hydrochloric acid contained in the gastric juice secreted by the glands of the proventriculus acts as a solvent on mineral matter, making its final absorption possible.

The gizzard does not contain any glands that secrete enzymes, but the breaking down of the feed particles by the gizzard hastens the digestion

of feed materially, especially when it is of a fibrous nature. Grit in the diet enables the gizzard to better perform this grinding function. The gizzard also acts as a filter so that no feed passes out until it is finely ground.

The liver secretes bile, which reaches the distal portion of the duodenum by means of two bile ducts, the one from the right lobe of the liver being enlarged to form the gall bladder. The bile emulsifies and dissolves the fats in feed so that enzymes can act on the fats more readily. The bile contains salts which help to neutralize the acid of the gastric juice, thus preparing the feed for further action by the juices secreted by the pancreas. The liver also serves in the synthesis of the uric acid that escapes in the urine.

The pancreas, which lies between the U-shaped loop of the duodenum, secretes pancreatic juice, which gains access to the duodenum by means of three ducts. The pancreatic juice is weakly alkaline in character and contains the enzymes amylopsin, which converts starch into maltose; trypsin, which converts any previously undigested proteins into proteoses, the latter into peptones and polypeptides, both of which are converted into amino acids; and lipase, which converts fats into glycerol and fatty acids. The glycerol and fatty acids are absorbed by the villi of the intestinal tract and upon being reformed into fats pass by the way of the lymphatic system into the blood stream.

Distributed throughout the small intestine are "Lieberkühn's glands," which secrete the intestinal juice containing the enzyme erepsin, which converts peptones into amino acids. The intestinal juice also contains the enzyme maltase, which converts maltose into glucose; and the enzyme sucrase, which converts sucrose into glucose and fructose. Aside from its digestive function, the small intestine also acts as an organ of absorption by absorbing soluble nutrients and inorganic salts.

The caeca aid in the digestion of the fiber contained in feed.

The large intestine serves in the absorption of water from the urine as it is delivered by the ureters from the kidney. The urine is expelled with the feces in the form of white paste.

The various mineral nutrients in the feed are usually absorbed from the intestine without undergoing any change in composition. In so far as known, most of the vitamins are also absorbed directly by the body without undergoing any change. Carotene, the precursor of vitamin A, is transformed in the liver into true vitamin A. Vitamin C is synthesized or manufactured in the bird's body. Cholesterol in the skin is transformed into vitamin D when birds have access to sunlight or ultraviolet light.

Wastage of Nutrients in Digestion. It is a significant fact that the nutrients absorbed by the fowl's body to enable it to perform its normal

functions and in the formation of new tissues and secretions are invariably smaller in amount than the nutrients that must be supplied in the feed for these purposes. Rarely is any nutrient contained in the feed completely digested, much less completely utilized. Moreover, the level of feeding affects the wastage of nutrients in digestion; for when the chicken is fed excessive amounts of feed, the nutrients are digested less thoroughly than when the chicken is fed a scanty diet. Then, again, nutrients that are not properly balanced in the diet apparently are not digested so well as when they are properly balanced. An excessive supply of any particular nutrient constitutes a wastage in feeding practice because a higher proportion of the nutrient remains undigested than when the optimum amount is fed.

THE METABOLISM OF NUTRIENTS

The metabolism of the nutrients involves the various processes they undergo from the time they enter the blood stream, for which they were prepared by the processes of digestion, until the waste products are finally excreted from the body.

Upon entering the blood stream, the nutrients, such as the amino acids and glucose, are carried to different parts of the body for tissue building, the development of secretions, and the production of energy. The circulatory system, therefore, serves a very important function in metabolism. The blood is continually in circulation and is composed largely of two kinds of cells, erythrocytes and leukocytes. The erythrocytes, or red-blood cells, contain a protein substance called "hemoglobin," which serves as a vehicle for carrying oxygen to different parts of the body.

The respiratory system also serves an important purpose in metabolism, inasmuch as the oxygen breathed in and transported to different parts of the body by the hemoglobin is absolutely essential in order that oxidation of the various nutrients may proceed. The oxidation products are water, carbon dioxide, and other gases; and the heat given off in the process is known as the "heat of combustion." The carbon dioxide is exhaled by the bird in breathing.

Hormones and Metabolism. Recent research work has demonstrated that the hormone secretions of the endocrine regulatory system sometimes have a very marked effect on metabolism. It has been demonstrated that several hormones have a pronounced effect in regulating various functions of the body. Some evidence has been secured showing that certain hormones tend to raise the level of metabolism of certain nutrients, whereas others, when secreted in excessive amounts, have a depressing effect on the metabolism of certain nutrients. Some hormones serve the purpose of maintaining a proper balance of nutrients in the blood stream.

The growth-promoting hormone secreted by the anterior pituitary is required for normal growth. Thyroxine secretion by the thyroid is absolutely necessary for normal growth in young chickens and for maintaining the normal level of metabolism in birds of all ages. The activity of the thyroid influences the metabolism of water and inorganic salts. The functioning level of the thyroid varies among strains of birds, and thus the rate of metabolism is affected. A hormone secreted by the adrenal glands mobilizes the carbohydrate stores in the body. These are only a few examples of the influence of hormones on metabolism.

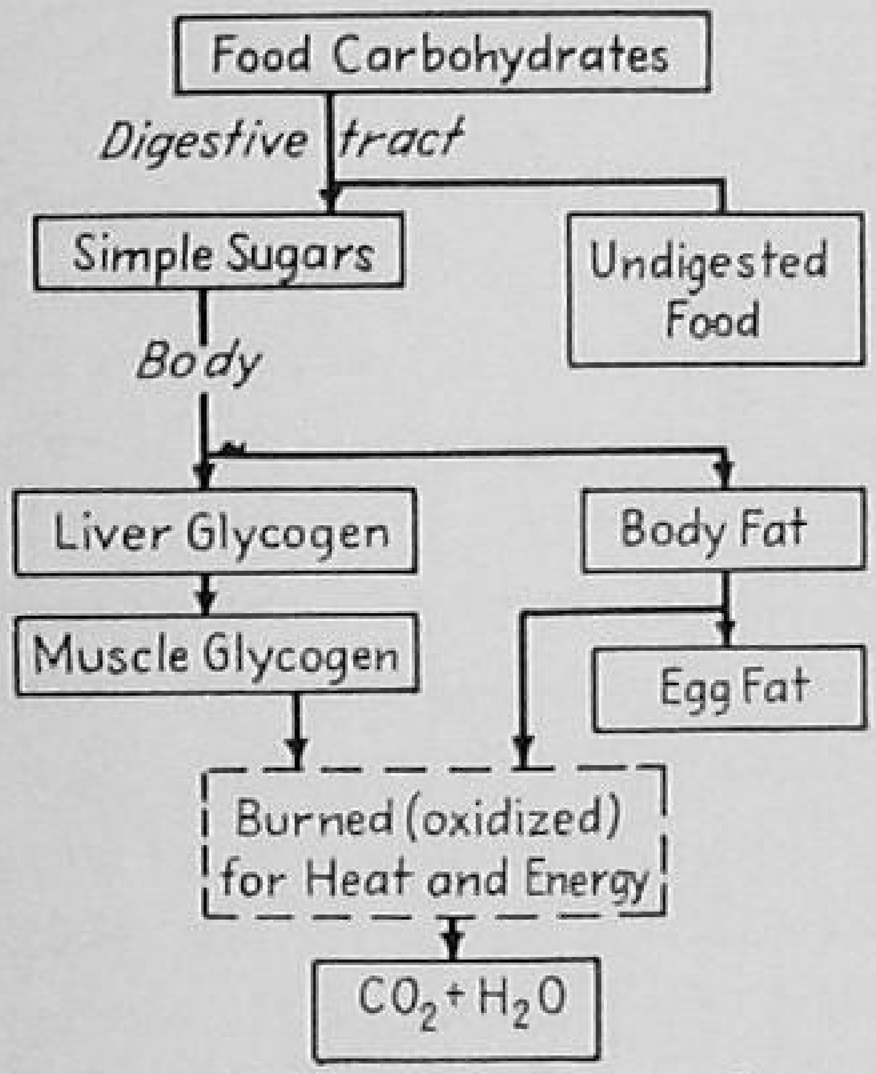


FIG. 154. Scheme illustrating the use of carbohydrates in the body. (*After Holst and Newlon.*)

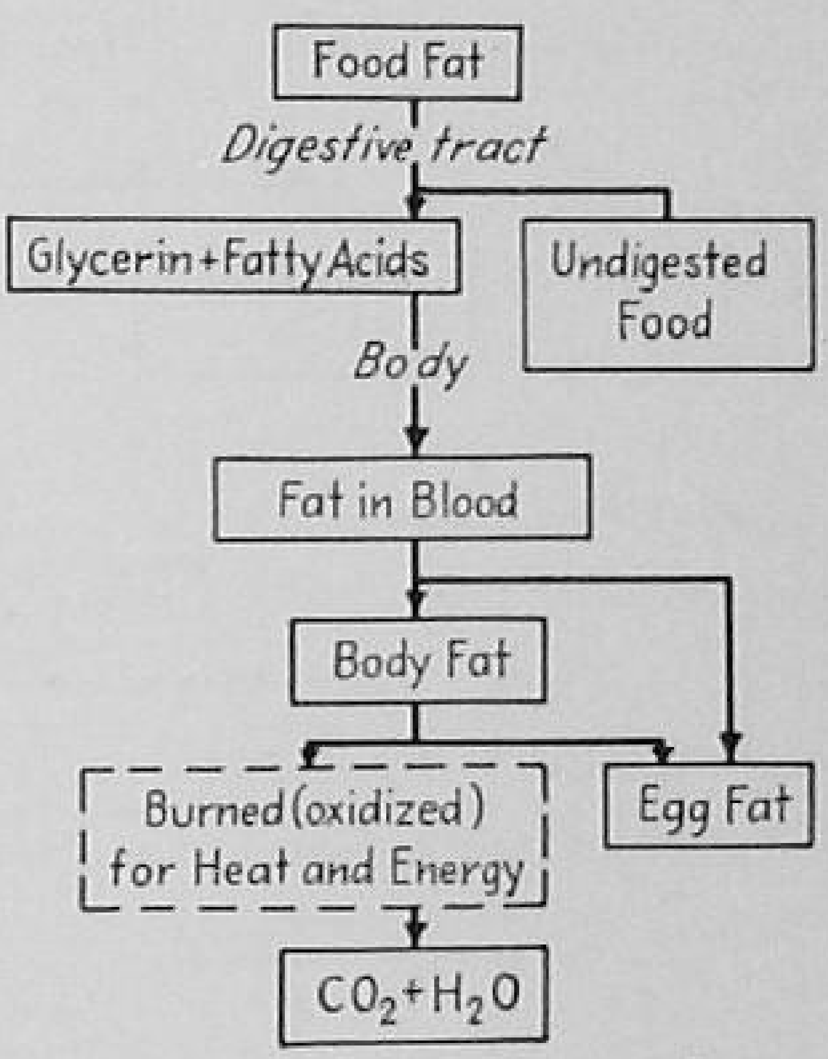


FIG. 155. Scheme illustrating the use of fats in the body. (*After Holst and Newlon.*)

Carbohydrate Metabolism. The carbohydrate of the blood stream is in the form of glucose, as observed previously. Upon being oxidized, the primary function that glucose serves is as a source of fuel. A portion of the glucose is used for the formation of a substance called "glycogen," which is stored principally in the liver to be oxidized for heat and energy. Any surplus of glucose is stored as fat.

Glucose in the blood stream may also be used in the formation of body fat and egg fat, the body fat being oxidized for heat and energy. A very small portion of the glucose in the blood stream is used in the formation of the carbohydrates of the body cells. Regardless of the proportion of carbohydrate nutrients contained in the diet, the percentage of glucose in the blood stream is nearly always constant, this being accomplished by hormones secreted by certain endocrine glands.

Fat Metabolism. As previously pointed out, most of the digested fats pass by way of the lymphatic system into the blood stream, the blood cells changing the neutral fats into what are called "phosphorized fats,"

which may be used as a source of energy or for storage or for the formation of what are known as "lipoids" of the cells and "sebaceous lipoids" of the skin.

Protein Metabolism. The different amino acids obtained by digestion from the proteins of the feed are carried by the blood stream to different parts of the body and serve in the formation of the amino acids in the tissues, organs, and other parts of the body. An excess supply of proteins may be used as a source of energy, but this is a relatively expensive process.

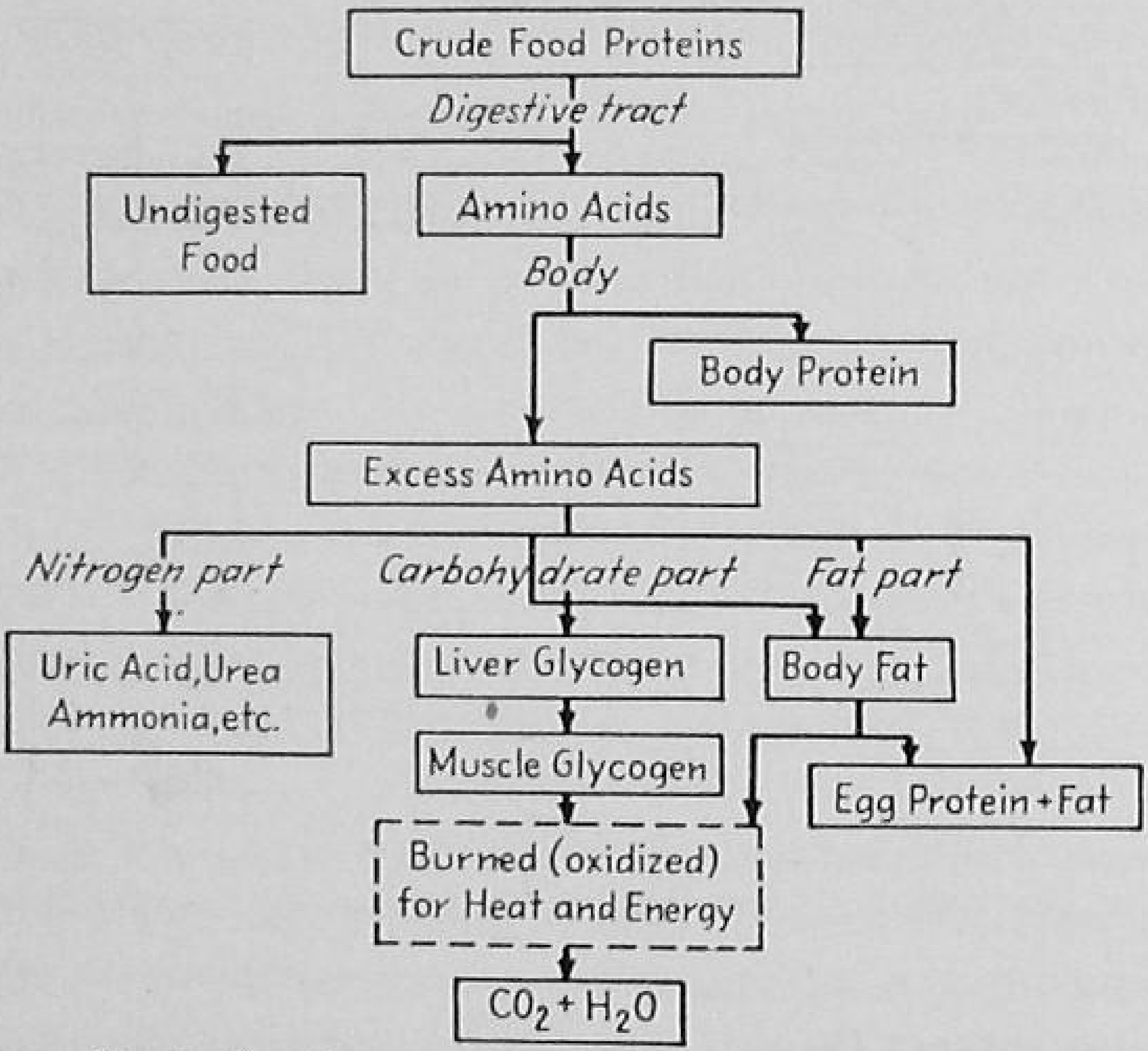


FIG. 156. Scheme illustrating the use of proteins in the body. (*After Holst and Newlon.*)

The nitrogen utilized is determined by the difference between the nitrogen absorbed from the digestive tract and the nitrogen in the urine. The nitrogen that is utilized when expressed as a percentage of that which is absorbed gives what is known as the "biological value" of the protein in question.

Mineral Metabolism. Comparatively little is known concerning the metabolism of the different mineral nutrients, although it has been shown definitely that the utilization of mineral nutrients is modified by many factors. For instance, the proper deposition of calcium and phosphorus in the growing chick is dependent upon an adequate supply of vitamin D. Calcium and phosphorus in the ratio of approximately 2 to 1, plus an adequate amount of vitamin D, are necessary for bone calcification.

The most efficient utilization of minerals is sometimes determined by their relationship in some body function. For instance, the hemoglobin

of blood with its incorporated iron is produced only in the presence of copper. It is apparent, therefore, that the utilization of iron is dependent on the presence of copper.

EXCRETION

The products excreted by the fowl include undigested materials and waste products resulting from the metabolism of the nutrients.

Feces. The feces comprise the undigestible portion of the feed intake, intestinal bacteria, certain digestive juices, and mineral material resulting from body metabolism. Manure includes the feces and urine and contains about 1.44 per cent nitrogen, 0.99 per cent phosphoric acid, and 0.39 per cent potash.

Urine. The fowl's urine consists principally of nitrogenous waste products plus water resulting from the various processes of metabolism. Liquid waste products pass out from the blood stream into the kidney and from the kidney through the ureters to the cloaca, from which they are excreted as urine. For the most part, the urine is a white pasty material which coats and is mixed with the manure. Approximately 65 per cent of the urinary nitrogen excreted by the fowl exists in the form of uric acid.

Carbon Dioxide and Water Elimination. The respiration of the fowl results in varying amounts of carbon dioxide and water being eliminated, depending upon the activity of the bird and level of egg production.

ENERGY PRODUCTION

Energy is required for the performance of all bodily functions, such as eating, breathing, digesting nutrients, growing, and producing eggs. Energy is derived from the feed consumed, the digestion and metabolism of the nutrients involving the release of energy.

Gross Energy. The gross energy value of various feedstuffs depends upon the amount of energy they furnish when completely oxidized (burned). Proteins and carbohydrates produce 4 Calories per g., being approximately equal in their energy values. Fats produce 9 Calories per g. or 2.25 times as much energy as proteins and carbohydrates. The Calorie is the amount of heat required to raise a kilogram (1,000 g.) of water 1°C.

Available and Net Energy. The gross energy of a feedstuff minus the energy lost in the feces, urine, and combustible gases represents the available energy. The available energy of a feedstuff minus the energy lost in the various processes of digestion and a portion of that involved in metabolism represents the net energy. The energy consumed in the processes of digestion takes the form of heat and helps to keep the fowl's body warm. The net energy of a feedstuff is first used for daily maintenance

requirements involved in the work performed by the various internal organs of the body and by the numerous muscles used in eating, breathing, and walking. Any surplus of net energy may be used for growth, or for fattening, or for the production of eggs.

Basal Heat Production. The basal heat production is the heat produced by an inactive fasting animal. The kind of tissue being oxidized can be determined from an estimation of the basal heat production obtained by measuring the oxygen consumption and carbon-dioxide elimination. The volume of oxygen consumed divided into the volume of carbon dioxide eliminated gives the respiratory quotient (R.Q.), that of fats being 0.7, proteins 0.8, and carbohydrates 1.0. Basal heat production and respiratory quotient determinations are useful in studying nutritive requirements.

The net nutritive value of feeds is determined by the extent to which the nutrients are digested and by the extent to which the digested portions are utilized in the body.

Coefficients of Digestion. The digestibility of a feed is expressed in terms of the "digestion coefficient," which refers to the percentage of the nutrient consumed that does not appear in the feces. In order to determine the digestion coefficient of a given feed, the exact chemical composition of the feed is first determined. Then definite amounts are fed, and the feces excreted during the experimental period are collected, weighed, and analyzed, the urine from the kidneys having been diverted by an artificial anus or, if the urine has not been kept separate, proper calculations are made.

Nutrient Requirements for Specific Purposes. The nutrients that are absorbed by the body system serve several different purposes in the process of metabolism. Several nutrients may be required for a specific purpose, or one nutrient may serve several purposes. The nutrient requirements for the different purposes enumerated previously may be most logically considered from the following standpoints: (1) maintenance, (2) growth, (3) fattening, (4) market-egg production, and (5) hatching-egg production.

The quantitative requirements of the different nutrients naturally increase as the chicken grows, and they vary in proportion depending upon whether chickens are being fattened or fed for market-egg or hatching-egg production.

NUTRITIVE REQUIREMENTS FOR MAINTENANCE

Whether a chicken is being fed for growth, fattening, or egg production, some of the feed given is used for the body processes which must go on in order to support life and maintain the body as a "going concern."

In order to continue the chicken's existence, aside from growing, adding tissue, or producing eggs, at least four requirements must be met: (1) the maintenance of normal body temperature, (2) a supply of energy necessary for muscular activity, (3) nutrients for the renewal of tissue, (4) the elaboration of secretions. The demand for feed to meet these requirements is referred to as the "maintenance requirements." A knowledge of maintenance requirements is necessary in order to understand the principles underlying poultry nutrition.

Energy Requirements for Maintenance. The various bodily processes, such as digestion and metabolism, are most efficiently carried on when the normal body temperature of approximately 107°F. is maintained. The amount of energy required for maintenance is affected by the age and size of the bird, sex, environmental temperature, and the degree of activity.

Heat production is more closely related to the surface area of the body than to the weight of the body.

The basal heat production of chicks at hatching time is slightly less than 550 Calories per sq. m. per day but rises to between 1,400 and 1,500 Calories at about 6 weeks of age, then decreases rapidly during the next several weeks. The basal heat production of mature hens is 800 Calories per sq. m. per day and that of mature cockerels about 850 Calories. Capons have a decidedly lower basal heat production per unit area.

Whenever the environmental temperature falls below the critical temperature of the chick or adult bird, there is a rapid increase in the metabolic rate, and the extra heat required to maintain normal body temperature must be supplied by extra feed in order to avoid the loss of energy. The critical temperature of the chick at hatching time is 96°F. An increase or decrease of 7° from the critical temperature causes about 15 per cent increase in metabolism, and at 70°F. the energy output is twice as great as at 96°F. The critical temperature of the adult fasting hen at rest is 62°F. It should be observed, however, that the critical temperature is not a constant factor but is influenced by such things as the amount of feed consumed and the activity of the bird. The higher the level of feed consumption, the greater the heat production. For birds in a normally active state the energy requirements are approximately 50 per cent greater than the energy requirements for basal heat production.

Protein Requirements for Maintenance. The need of protein, or other source of available nitrogen, for maintenance appears to be related to the need of replacing the essential nitrogenous constituents of the body which are continually being lost. This breakdown, or catabolism, is referred to as "endogenous" catabolism and does not seem to be affected by the ordinary environmental factors or by the bodily activities.

The endogenous nitrogen can be used as a measure for the body nitrogen which must be supplied by the feed protein for protein maintenance, provided certain assumptions are made as to the losses in metabolism. On this basis, it appears that the endogenous nitrogen amounts to 2 mg. per Calorie of heat production in all species.

Mineral Requirements for Maintenance. Many of the mineral elements undergo a very active metabolism in connection with the various processes that are necessary for the normal body functions in maintenance. The mineral elements are not necessarily used up and excreted in the process, however, as in the case of energy and protein metabolism. On the other hand, there is always some loss of minerals during maintenance, the amount excreted and the amount required for maintenance depending upon a variety of factors, including the nature of the mineral relationships in the diet. Only a few of the numerous minerals essential for normal body functions are ever likely to be sufficiently lacking in normal diets to merit attention as regards their requirements in maintenance.

Vitamin Requirements for Maintenance. Very little work has been carried on to determine vitamin requirements for maintenance.

NUTRITIVE REQUIREMENTS FOR GROWTH

As compared with most other domestic animals, the chicken grows more rapidly, doubling its weight in about 2 weeks and increasing it by ten times in about 6 weeks. The rate of growth is determined by the inherent capacity for growth, the kind and amount of feed consumed, and the environmental conditions under which the chicken is kept.

The Nature of Growth. Growth is a very complex process involving much more than increase in size, for in the growth of the body as a whole there must also be a completely coordinated growth of all of its parts. For each species there is a characteristic rate of growth and a characteristic adult size, and, in a general sense, these two statements apply to the various breeds of chickens. Maximum size seems to be determined by heredity, but since nutrition is an essential factor affecting rate of growth and the attainment of maximum size, it is obvious that the most satisfactory diet is one that enables the chicken to take full advantage of its heredity.

Increase in body size involves an increase in the organs and structural tissues such as bone and muscle, this true growth being distinguished from the increase that results from the deposition of fat in the reserve tissue. True growth implies, therefore, an increase in water, protein, and mineral matter, and involves an adequate supply of energy-producing nutrients to support the various growth processes and the vitamins

which are essential for the attainment of physiological well-being and the most efficient utilization of feed.

The fact that males grow faster than females, and birds belonging to the general-purpose breeds grow faster than Leghorns, is substantiated by the data given in Table 34 for Rhode Island Reds and White Leghorns.

TABLE 34. APPROXIMATE AGE IN WEEKS BY WHICH CERTAIN AVERAGE LIVE WEIGHTS ARE ATTAINED BY RHODE ISLAND REDS AND WHITE LEGHORNS (National Research Council, 1944)

Average live weight, lb.	Approximate age, weeks			
	Rhode Island Reds		White Leghorns	
	Males	Females	Males	Females
0.5	3.9 to 5.1	3.9 to 5.1	4.0 to 5.3	4.0 to 5.3
1.0	5.8 to 7.9	5.9 to 8.0	6.0 to 8.2	6.6 to 8.4
1.5	7.6 to 10.1	7.7 to 10.1	7.8 to 10.3	9.0 to 11.0
2.0	9.2 to 11.9	9.5 to 12.5	9.5 to 12.3	11.7 to 14.1
2.5	10.7 to 13.8	11.2 to 14.5	11.2 to 14.5	14.7 to 17.7
3.0	12.4 to 15.7	13.2 to 16.6	13.6 to 17.0	18.1 to 22.4
3.5	13.7 to 17.1	15.6 to 18.6	16.7 to 20.3	23.6 to 31.0
4.0	14.9 to 18.7	18.3 to 21.2	20.4 to 25.3	
4.5	16.1 to 20.2	21.3 to 24.7	25.7 to 36.0	
5.0	17.3 to 21.9	25.0 to 29.8		

The figures for age in weeks that the respective average live weights have attained indicate considerable variation in rate of growth, a condition which exists among strains of the same breed. The figures given in Table 34 pertain, for the most part, to chickens raised under normal farm conditions. There are strains of Rhode Island Reds and White Leghorns that attain the specified average live weights at an earlier age than those given in Table 34. Also, there are strains of New Hampshires and White Plymouth Rocks that attain the specified average live weights at a much earlier age than those given in Table 34, especially in the case of those strains that have been bred specifically for rapid growth. Attaining a specified average live weight at a minimum age in weeks is the goal to be desired from a purely economic standpoint.

The Growth Curve. When a baby chick is fed a so-called "normal" diet, growth proceeds at a more or less continuous rate until maturity is attained. Although the chicken increases steadily in weight, the percentage increase in body weight from week to week throughout the growing period is not the same. In most cases body weight is approximately

doubled each 2-week period up to the end of 6 weeks, but after that the percentage gain in weight is lower.

The growth curve is divided into two principal segments, one of increasing and the other of decreasing slope. The point of inflection of the curve depends upon the kind of diet and the amount of feed consumed

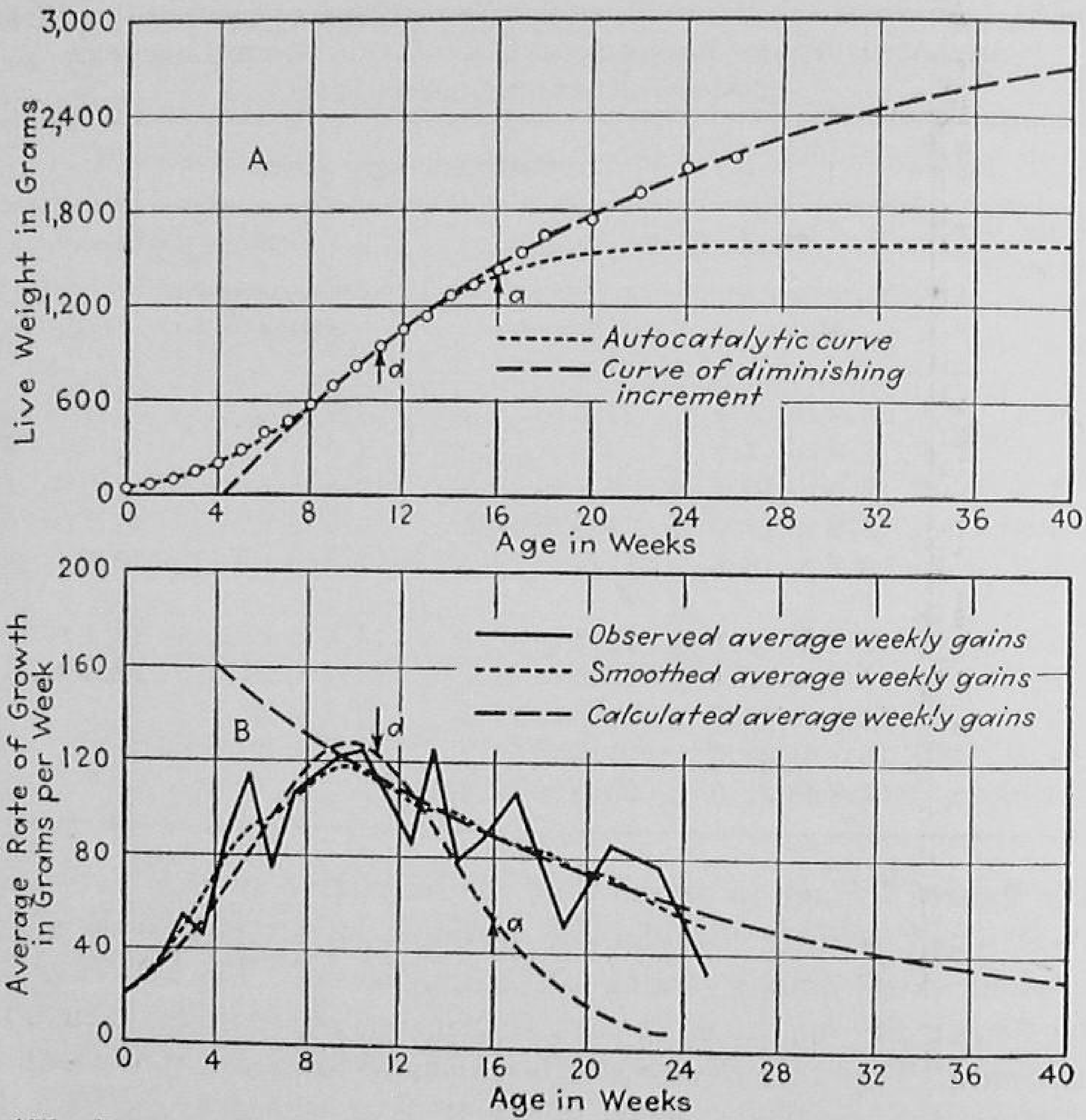


FIG. 157. Data on growth in Rhode Island Red pullets plotted to show growth curve in (*A*) and rate of growth in (*B*). In each case *a* marks the end of the age interval to which the autocatalytic curve was fitted, and *d* marks the beginning of the interval to which the curve of diminishing increment was fitted. (*H. W. Titus and M. A. Jull.*)

as well as other factors but usually occurs between the tenth and the sixteenth week.

Growth in Relation to Feed Consumption. There is a well-defined relationship between the rate of growth and the amount of feed consumed during any given period. In other words, the amount of feed consumed rather than the age of the chicken determines to a large extent the rate of growth.

From the standpoint of the utilization of feed, it has been shown that

for each successive 1,000 g. of feed consumed by growing chickens there is a relatively smaller increase in live weight. In other words, as the chicken increases in size proportionately more of the feed is used for the maintenance of the body and proportionately less of the feed is used for growth. The utilization of feed for live-weight increase follows the law of diminishing increment.

From a purely practical standpoint, the fundamental principle of increase in body weight in relation to the amount of feed consumed during

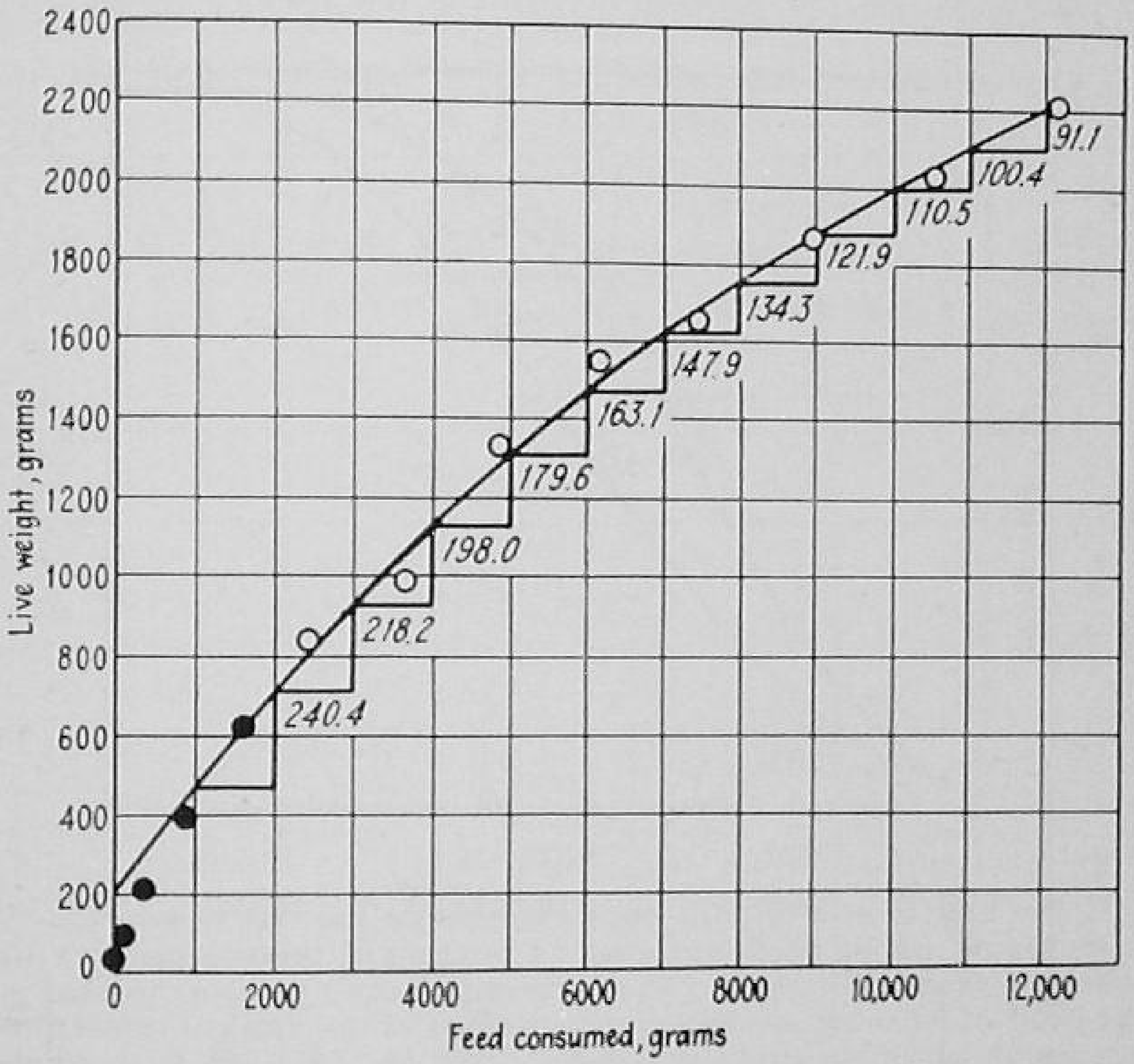


FIG. 158. Growth of chickens in relation to feed consumption. Each successive 1,000 g. of feed produces about 90 per cent as much increase in live weight as the preceding 1,000 g. (*M. A. Jull and H. W. Titus.*)

about the first 6 weeks may be stated in either one of the following two ways: (1) The average live weight of chickens at any time during the period could be estimated with reasonable accuracy from a knowledge of the amount of feed consumed; (2) the average weight of the chickens enables one to estimate with reasonable accuracy the amount of feed they have consumed. After about the first 6 weeks the proportion of the total diet that is utilized for growth decreases relatively, although, of course, the absolute amount of the nutrients required for maintenance and for growth increases as the birds increase in size.

Energy Requirements for Growth. On the basis of per unit of body weight, the amount of energy represented by the growth tissue formed

decreases with age, but the amount of energy stored per unit of gain increases with age.

The sum of the energy of the tissue formed plus the basal metabolism increased by a factor for activity constitutes the net-energy requirement for growth. The average daily expenditure in muscular activity has been estimated to be 50 per cent of that required for maintenance.

Protein Requirements for Growth. The increase in body size as the result of true growth is largely due to increases in water and protein. In a well-balanced diet its protein content is the outstanding factor that

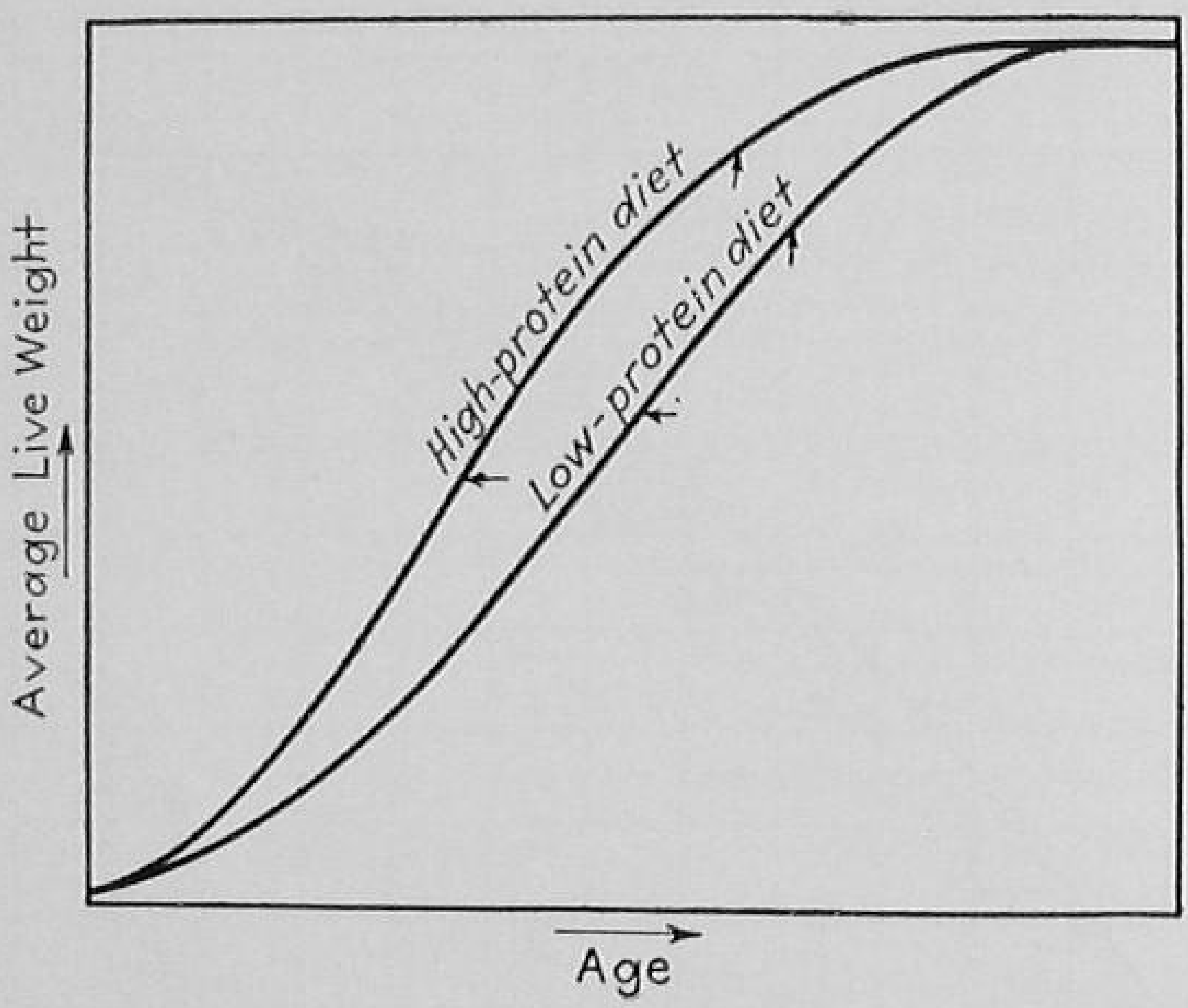


FIG. 159. A diet high in good-quality protein speeds up the rate of growth. This illustration shows typical curves resulting from the plotting of the average live weight of a group of chickens against their age. The horizontal arrows pointing toward each curve indicate the point of inflection of the growth curves, and the vertical arrows indicate the approximate age at which egg production begins. (*H. W. Titus and J. C. Hammond.*)

determines the rate of growth attained. The actual amount of protein required for optimum growth is considerably in excess of the amount stored in the body because the loss of protein in digestion and the wastage of protein in metabolism must be provided for in the diet. The amino-acid requirements for growth are more exacting than those for maintenance.

Moreover, the amount of protein required for growth is determined to a great extent by the nutritive value of the protein intake. The efficiency or biological value of the protein of a given diet is measured as the percentage of the total intake that is stored. It has been pointed out previously that the various protein supplements vary considerably among themselves with respect to their biological values for growth-promoting purposes.

The fact should be kept in mind that certain proteins mutually supplement each other, so that the resulting amino-acid mixture usually has a biological value exceeding that of either protein when fed separately.

The results of experimental work on growth and efficiency in relation to level of protein in the diet are indicated in a general way by the data given in Table 35.

TABLE 35. RELATIVE EFFECTS IN PER CENT OF DIFFERENT LEVELS OF PROTEIN INTAKE ON EFFICIENCY OF FEED UTILIZATION, GROWTH, AMOUNT OF FEED REQUIRED FOR ATTAINING MAXIMUM BODY WEIGHT, AND TIME REQUIRED TO ATTAIN MAXIMUM BODY WEIGHT IN MALE CHICKENS
(H. W. Titus, 1939)

Level of protein intake	Efficiency of feed utilization	Maximum live weight attained	Amount of feed required for attaining maximum weight	Length of time required to attain maximum weight
13	67.7	97.6	144.1	119.9
14	80.6	97.9	121.3	111.7
15	87.3	98.2	112.5	107.8
16	91.5	98.6	107.7	104.6
17	94.6	98.9	104.6	102.6
18	97.2	99.2	102.1	101.5
19	98.7	99.5	100.7	101.0
20	99.7	99.8	100.1	100.5
21	100.0	100.0	100.0	100.0
22	97.9	100.2	102.3	99.7
23	94.3	100.4	106.4	99.5
24	90.2	100.5	111.4	99.4
25	85.6	100.6	117.5	99.2

The data given in Table 35 show that as the protein level of the diet increases from 13 to 21 per cent, there is a steady increase in efficiency of feed utilization. On the other hand, as the protein level of the diet increases from 21 to 25 per cent, there is a steady decrease in efficiency of feed utilization. The data indicate that for growth, the optimum level of protein in the diet is approximately 20 to 21 per cent. Although efficiency of feed utilization is at its optimum level when the diet contains approximately 21 per cent protein, it may be slightly more economical to feed diets containing 19 to 20 per cent protein because of their relatively lower cost.

A diet containing an adequate level of protein content stimulates early growth, but the maximum live weight eventually attained is usually

independent of the per cent of protein in the diet. On the other hand, birds on a high per cent protein diet attain maximum weight considerably earlier than those on a low per cent protein diet, but the advantage of a high per cent protein diet is gradually lost after the birds are about half grown. During most of the period of active growth, less feed is required to produce gains in live weight: this advantage is gradually lost as maximum live weight is approached because the protein requirement decreases with age. An interesting fact to be kept in mind, however, is that protein is more efficiently utilized when the diet contains a low per cent of protein than when it contains a high per cent.

Finally, since the advantage of a diet containing a high per cent of protein is gradually lost after the chickens are about half grown, it would appear desirable to feed a diet containing about 20 to 21 per cent protein for the first 8 to 12 weeks, especially if broilers are being produced, and thereafter gradually reduce the protein to about 16 per cent of the diet as the birds grow older.

Mineral Requirements for Growth. Of the numerous minerals that are essential in the diet to promote normal growth, the calcium and phosphorus needs have been studied most extensively because they have been found to be of such great importance for the normal development of the skeletal or bone structure of the chicken. It should be observed here, however, that the most efficient utilization of the calcium and phosphorus content of the diet depends upon an adequate supply of vitamin D. The phosphorus contained is largely in the relatively unavailable form of phytin phosphorus and must be supplemented from such sources as steamed bone meal. The diet for growing chickens should contain 1.0 per cent of calcium and 0.6 per cent of phosphorus, not less than one-half of which should be from other than plant sources.

The sodium and chlorine requirements for growth are met, for the most part, by the addition of 0.5 to 1.0 per cent of common table salt (sodium chloride). Manganese should be added to the diet at the rate of 30 to 50 parts per million or about ¼ lb. of manganese sulfate per ton of feed. Most of the other minerals required for normal growth are supplied in commonly used feedstuffs.

Vitamin Requirements for Growth. In the discussion in the fore part of this chapter it was pointed out that many of the vitamins required for normal growth are contained in various feedstuffs. Vitamins A, D_3, and riboflavin are among those most likely to be deficient in diets for growing chickens. Supplements of vitamin D are especially important in the case of birds grown in confinement without access to sunshine.

The diet for growing chickens should contain at least 1,350 International units of vitamin A per pound of feed. The International and

U.S.P. (United States Pharmacopoeia) unit of vitamin A is 0.0006 g. (0.6 gamma) of pure beta-carotene.

Chickens grown in confinement require about 175 A.O.A.C. units of vitamin D per pound of feed. The A.O.A.C. (Association of Official Agricultural Chemists) chick unit of vitamin D is the calcium-depositing efficiency for the chick of a U.S.P. unit of cod-liver oil.

The amount of riboflavin required for normal growth varies with age; during the first 2 weeks about 1.5 mg. per lb. of feed are required; this amount decreases to about 1.3 mg. per lb. of feed from 3 to 8 weeks of age; after 8 weeks of age, about 0.45 mg. per lb. of feed is apparently sufficient. The recommended allowances in starting and growing rations are 1.6 and 0.9 mg. per lb., respectively.

NUTRITIVE REQUIREMENTS FOR FATTENING

The fattening of chickens is primarily for the purpose of improving the quality of poultry meat by the addition of fat to the tissues. During the early stages of growth, fat is deposited in the body to a small extent only. During the later stages of growth, however, it is possible to fatten chickens readily. Much of the fat is deposited immediately under the skin, the balance being located around certain organs, such as the gizzard and intestines, and in the muscles.

Ingested protein can be transformed into body fat, the nonnitrogenous residue of certain amino acids being changed into glucose, which is readily changed into fat. Under normal conditions, however, most of the fat deposit is obtained from carbohydrates plus that obtained from ingested fat during the fattening process. The transfer of carbohydrate into fat is much more efficiently carried out than the transfer of protein into fat. For this reason, diets for fattening chickens usually contain only about 15 per cent protein.

Apparently there is very little wastage of energy in the metabolism of fat deposition. In the fattening of a mature bird, approximately 7 Calories per g. of gain in body weight represents the energy requirement, and approximately 0.2 g. of net protein per gram of gain in body weight represents the protein requirement. The amount of energy and protein made available in the fattening diet should provide for the losses in energy that occur in digestion and the losses in protein that occur in digestion and metabolism.

NUTRITIVE REQUIREMENTS FOR MARKET-EGG PRODUCTION

In 1 year a layer may produce five times as much dry matter in the eggs she lays as is contained in her body, indicating an intensive metabo-

lism and very large nutritive requirements. The requirements for energy, protein, carbohydrates, minerals, and vitamins are determined to a considerable extent by the rate of egg production. The ability to lay well is an inherited characteristic, and nutrition can do no more than allow the bird to express its maximum laying potentialities.

A 2-oz. egg (56.7 g.) contains approximately 90 to 95 Calories of gross energy, 7.5 g. of crude protein, and 2 g. of calcium.

Part of the feed consumed by a maturing pullet is utilized for growth and the remainder for maintenance and egg production. After the bird has reached maturity, feed consumed is used primarily for maintenance and egg production. After maintenance requirements have been met, the amount of feed consumed per egg produced is the same for eggs of the same size. Obviously, as the level of egg production increases, the percentage of total feed intake required for maintenance decreases.

Energy Requirements for Egg Production. The energy requirements for maintenance in layers varies according to body size, largely irrespective of the breed of chickens. The energy requirements of 4-lb. pullets are supplied by 0.145 to 0.160 lb. of feed per bird per day, and the energy requirements of 5.5-lb. pullets by 0.205 to 0.227 lb. of feed per bird per day. The quantity of feed required for the production of a 2-oz. egg is between 0.78 and 1.0 lb.

Protein Requirements for Egg Production. With respect to protein requirements for egg production, it has been estimated that laying birds require approximately 0.625 g. digestible protein per pound body weight per day for maintenance and 12.5 g. digestible protein for each 2-oz. egg produced. The diet for the laying flock should contain about 15 to 17 per cent crude protein, the 17 per cent protein diet being especially desirable for pullets during the first 4 months of their first laying year. In most cases at least 25 per cent of the protein supplements should be of animal origin.

Mineral Requirements for Egg Production. The mineral requirements of layers are met rather readily, even though the needs for calcium are relatively great. A 2-oz. egg contains about 2 g. of calcium, so that a 200-egg hen produces about fourteen times as much calcium as is contained in her body. The diet for layers should contain about 2.25 per cent of calcium, about 0.75 per cent of phosphorus, about 0.75 per cent salt, and small quantities of manganese and iodine, including whatever amounts of these nutrients are contained in the other ingredients of the diet.

Vitamin Requirements for Egg Production. Among the various vitamins necessary for satisfactory market-egg production, vitamins A and D are probably the only ones that need special consideration, except pos-

sibly riboflavin, because most of the others are usually supplied in sufficient quantities in most commonly fed diets.

For satisfactory egg production, apparently a minimum of 2,000 I.U. of vitamin A per pound of feed are required. When laying hens are kept in confinement in the absence of sunshine, the diet must be supplemented with vitamin D. Approximately 300 A.O.A.C. units of vitamin D_3 per pound of feed constitute the minimum requirements.

Nutritive Requirements for Molting. The periodical shedding and renewal of feathers by the laying hen presents a problem of interest from the standpoint of possible special nutritive requirements that must be met during the molting process. The close association that exists between the onset of the molt and the cessation of egg production suggests a shift in the requirements from those of egg production to those of feather growth. Although the weight of a hen's feathers amount to only about 5 per cent of her total body weight, her feathers contain about 20 per cent of the total protein in her body. Feathers have a relatively high content of sulfur, indicating a strong demand for cystine and methionine.

Various observations indicate clearly the need for an adequate supply of the amino acid cystine for feather growth. In one experiment it was found that with nonmolting mature Rhode Island Red hens the average daily loss of endogenous nitrogen amounted to 144 mg. per kg. of body weight, whereas in molting hens the daily loss amounted to 219 mg. per kg. of body weight. When 145 mg. of cystine was added to the diet of molting hens, it was found that the average daily loss of endogenous nitrogen was 137 mg. in contrast to a loss of 239 mg. per kg. of body weight with other molting hens not fed cystine. The feeding of cystine exerted a protein-sparing effect out of proportion to its nitrogen content, thus suggesting that for normal feather growth cystine is important.

NUTRITIVE REQUIREMENTS FOR HATCHING-EGG PRODUCTION

The results of numerous experiments carried on at different institutions during recent years have demonstrated clearly that certain diets which are quite satisfactory for market-egg production are relatively unsatisfactory for hatching-egg production.

Although the nutrient requirements of breeders are the same, with minor exceptions, as those for layers, more care must be exercised in providing breeders with proteins of high quality and more attention must be given concerning the optimum supply of certain vitamins, especially in the case of breeding stock kept in confinement.

The requirement of vitamin A for hatching-egg production is greater than for market-egg production. For the former approximately 2,000 I.U. constitute the minimum requirement.

In the case of breeding stock kept in confinement, great care should be taken to ensure an adequate supply of vitamin D_3, the requirement of which is greater than for layers producing market eggs. About 350 A.O.A.C. units per lb. of feed is the minimum requirement.

It is particularly important to provide an adequate supply of riboflavin in breeding-stock diets. One reason why breeding hens kept in batteries are likely to produce eggs having poor hatchability as compared with breeding stock kept on the floor is because the latter have access to feces, which contain riboflavin. An adequate supply of riboflavin in the breeding-stock diet is necessary to provide for normal growth of the embryo and in order that the chicks produced may have an adequate storage of riboflavin in order to permit optimum growth.

A deficiency of manganese in the diet of the breeding stock results in decreased hatchability, and the chicks that hatch are more susceptible to perosis.

The requirements of folic acid are higher for breeding stock for sustained high hatchability than for layers for market-egg production.

A marked deficiency of vitamin E in the diet of breeding stock results in sterility; biotin is necessary for normal embryo development; vitamin K is necessary for normal blood clotting in chicks.

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CHAPTER 10

FEEDING PRACTICE

Successful feeding practice is based on a knowledge of the purpose served by the various nutrients and their requirements for growth, fattening, and market-egg and hatching-egg production. Having discussed these latter problems in the preceding chapter, it is desirable in this chapter to discuss the principal sources of nutrients and the combination in which different feedstuffs should be fed to produce the desired results most efficiently.

Although most plant and animal products used in feeding poultry contain several of the necessary nutrients, the proportion in which these nutrients occur often varies widely, especially as between plant and animal products. A feedstuff is usually used as the chief source of a certain nutrient, although it may contain other nutrients in considerable quantities.

By far the largest proportion of the diet fed to poultry consists of cereal grains and their by-products. They are fed primarily as a source of energy. They are relatively deficient in protein and quite deficient in one or more of the essential amino acids, including lysine and tryptophan. Cereal grains are also deficient in certain minerals and vitamins. Therefore, the cereal grains and their by-products used in feeding poultry must be supplemented with feedstuffs relatively rich in the essential amino acids and with certain minerals and vitamins.

The various feedstuffs are classified as follows: (1) carbohydrates or energy-producing feedstuffs, (2) protein supplements, (3) mineral supplements, and (4) vitamin supplements. In addition, water is a nutrient, and there are certain miscellaneous feedstuffs the use of which may be justified under certain circumstances. Since water regulates the body temperature, performs an important function in digestion and metabolism, and comprises a relatively high proportion of the egg and poultry tissue, it is discussed first.

WATER

The cereal grains that make up the largest share of the poultry diet contain, on the average, from about 8 to 12 per cent of their air-dry weight in the form of water and, therefore, do not apply nearly enough water in proportion to the needs for growth, maintenance, fattening, or

egg production. Birds can live for a longer period without feed than without water.

Additional water must be supplied, and this is usually accomplished by making available liberal quantities of well, spring, river, or rain water. Deep-well water is invariably harder than rain water and, within the same geological formations, is also harder than lake or river water. Water containing alkalies is apt to be more harmful than water containing neutral salts. Water containing excessive amounts of such minerals as fluorine and selenium is toxic in its effect.

FIG. 160. Clean water is provided at all times with this watering system. The birds drink from overhead nipples spaced along the water supply line. A wire platform surmounts the drain trough, which catches the slight amount of waste water. (*H. Anger, Broiler Equipment Company.*)

An adequate supply of water should be available at all times. A flock laying at a high rate requires considerably more water than hens laying at a low rate. In sections of the United States when morning artificial lighting is practiced, it is important to have drinking water available when the birds leave the roosts. This can be accomplished by electrical heating devices, such as described in Chap. 8.

CARBOHYDRATE FEEDSTUFFS

Yellow corn, wheat, oats, and barley are the most commonly used cereal grains in feeding poultry. Yellow corn is a more potent source of vitamin A than are the others mentioned, otherwise these four grains have approximately equal feeding value when compared pound for pound on a

fiber-free basis. Although the cereal grains constitute the chief source of carbohydrates in poultry diets, proteins, minerals, and vitamins are also present.

Barley. This cereal is a good feed for poultry, though not quite so palatable as corn or wheat. Moreover, heavyweight barley (48 lb. per bu.) is more palatable than lightweight barley. It contains more digestible organic matter than oats but not so much as corn. Scabbed barley has been found as satisfactory for poultry-feeding purposes as normal barley.

Barley meal is sometimes used in fattening poultry, in which case heavyweight grain should be used, and it should be ground evenly, or the hulls may cause trouble in the chicken's crop.

Buckwheat. Because of its high fiber content, color, and relative unpalatability, buckwheat is rarely used in feeding poultry except sometimes in the form of buckwheat middlings for fattening.

Corn. Since it is the most abundant grain produced in the country, and since it is very palatable and readily digested, corn is one of the most valuable sources of carbohydrates. There is often considerable variability in the protein content of different varieties of hybrid corn, several having a lower protein content than regular yellow corn. Yellow corn contains cryptoxanthin and supplies vitamin A and is therefore superior as a feed to white corn. Both white and yellow corn are deficient in nicotinic acid. It is best to use Federal Grade No. 2 corn, or better, the former weighing at least 53 lb. per bu. and containing not more than 15.5 per cent moisture.

Corn meal (ground whole corn) has the same feeding value as the whole grain and is used extensively in fattening diets as well as for growing chicks and laying hens. Coarsely ground corn is more palatable than finely ground corn. Usually, the more recently that corn is ground prior to being fed, the higher the feeding value.

Corn hominy is made up of the hull, germ, and part of the starch cells and is a good poultry feed.

Sorghum Grains. Sorghums may be used to replace a small portion of corn in the diet, depending upon the price of each. The sorghums include: emmer, feterita, hegari, kafir, millet, and milo. All are deficient in vitamin A, thus making them somewhat less desirable than yellow corn. Milo may be used to a greater extent than the others as a substitute for yellow corn.

Oats. Whole oats are relatively higher in fiber content than corn, wheat, and barley but can be used in diets that are otherwise low in fiber content. Oats of poor quality should never be used. Federal Grade No. 1, weighing at least 32 lb. per bu. should be used. Finely ground oats

are commonly used in mashes. Sprouted oats used to be fed extensively years ago, but now it is recognized that they have no greater feeding value than unsprouted whole oats.

Rice. Because of its relatively high carbohydrate content and high digestibility, rice is a satisfactory feed for poultry, and in addition it has a regulating effect on the bowels. Its use in poultry diet is limited, however, because it is in such demand by human beings.

FIG. 161. Left, a dry-mash feeder that keeps feed wastage at a minimum. (*H. Anger, Broiler Equipment Company.*) Right, pullets feeding from a hopper equipped with wire guards to prevent wastage of feed.

Rye. Although comparing favorably with wheat in composition, rye is not a palatable feed and, if fed in considerable quantities, sometimes causes digestive disorders. The droppings often contain a pasty material so that the feces tend to cling to the chickens' feet.

Wheat. This cereal is extensively grown and is widely used as a source of carbohydrates because of its palatability and ease of digestibility. The protein content of wheat may vary from about 10 to 13.5 per cent, depending upon the section of the country in which it is grown. Soft wheats are as valuable for poultry-feeding purposes as hard wheats. Shrunken wheat, provided it is not so badly shrunken as to affect its palatability, can often be used to good advantage because much of it is not suitable for milling purposes.

Wheat bran consists of the outer layer of the wheat kernel. It has laxative properties but is low in the digestibility of its organic matter.

Wheat middlings contain a higher percentage of carbohydrates and fats and less fiber than wheat bran. As turned out from the mills, different lots of wheat middlings may vary widely in their feeding value.

Wheat screenings are low grades of wheat frequently mixed with foreign materials, particularly weed seeds. They are usually of questionable value unless of very high quality, *i.e.*, free from impurities and weed seeds having toxic properties.

Wheat shorts are very similar to wheat middlings. Shorts comprise the outer portions of the wheat kernel, except the outer layer which goes to make bran.

Ground whole wheat may be used as a substitute for wheat bran and wheat middlings when they are not available. However, wheat that has been ground finely tends to be sticky when eaten by birds.

ANIMAL-PROTEIN SUPPLEMENTS

It has already been observed that the cereal grains are deficient in certain essential amino acids. In addition, cereal grains have a lower protein content than eggs and poultry flesh. Because of these two facts, it is necessary to use certain quantities of protein supplements in order to provide a properly balanced diet to promote growth and produce eggs most efficiently.

Protein supplements are usually available as finely ground concentrates and may be of animal or plant origin. These concentrates are added to the mash portion of the diet in such proportions that the total feed intake contains the proper level of good-quality protein to give the most satisfactory results for the particular purpose for which the diet is being fed.

Since animal-protein supplements are good sources of the essential amino acids that are deficient in cereal grains and their by-products as well as in plant-protein supplements, it is easily understood why at least 25 per cent of the protein supplement should be of animal origin. Animal-protein supplements contain certain minerals and vitamins which are deficient in many plant-protein supplements, this being another reason for using animal-protein supplements in preparing well-balanced diets.

Blood. Fresh blood from slaughtered farm animals is sometimes used in wet mashes. Dried blood meal, because of its unpalatability and the relatively low biological value of its protein, is not a satisfactory feedstuff for poultry. Blood meal is deficient in isoleucine, which may account for its relatively low feeding value.

Chicken Scrap. The inedible viscera obtained in poultry-dressing plants, when dried and ground, makes a palatable and satisfactory feed for poultry.

Fish Meal. Inedible by-products of the fishing industry and whole fish are dried and ground and used extensively in feeding poultry. Fish meal must not contain more than 3 per cent salt. If heads and tails are used, the feeding value of the meal produced is lowered. Vacuum-dried fish meals are superior to much of the commercially prepared meat scrap. The protein content of fish meal is from 55 to 60 per cent. High-quality fish meal is apparently a complete source of amino acids. Certain fish meals contain vitamin B_{12}.

Fish Solubles. Condensed fish solubles are obtained by condensing the water resulting from the extraction of oil from fish. Water-soluble factors contained in fish-press water, as well as protein, are of value as supplements in certain kinds of diets. Stickwater meal enhances the value of protein supplements that are low in riboflavin and contains nicotinic acid, pantothenic acid, and bitamin B_{12}.

Insects. Fowls on range usually have access to large numbers of insects, which have a high protein content.

Hatchery Residue. Infertile eggs and dead embryos in commercial hatcheries constitute the chief by-products of the hatchery industry. Since some of the eggs may contain the organism that causes pullorum disease, hatchery by-products should be boiled at least 30 min. in order to kill the organism. The by-products are put through a sausage mill, then coagulated, and dried. The dried meal contains about 35 per cent protein, 30 per cent fat, and 30 per cent minerals.

Meat Scrap. This product is used extensively in poultry diets as a protein supplement and consists of the dry-tendered residue from animal tissues exclusive of horn, hoof, manure, and stomach contents, except portions unavoidably included. The protein content of meat scrap varies from about 45 to 60 per cent, depending largely upon the amount of bone present. If the finished product contains more than 10 per cent of phosphoric acid, it must be labeled as meat and bone scrap.

Meat scrap containing a high percentage of glandular tissue is superior to meat scrap containing a high percentage of connective tissue. The vitamin content of meat scrap is determined to a large extent by the percentage of glandular tissue present and the temperature employed in processing. During recent years it has been found that, in most cases, the better grades of meat scrap are not equal to the better grades of fish meal as protein supplements. Meat scrap provides a surplus of glycine and arginine but is deficient in tryptophan and the sulfur amino acids, cystine and methionine.

Milk Products. Milk in various forms has always been used extensively as a protein supplement. The proteins of milk are almost completely digestible. It is also relatively rich in riboflavin, thus being valuable for breeding stock used to produce hatching eggs and for growing chickens. Lactose or milk sugar contained in milk favors the development of acid-producing bacteria in the intestines of birds, thus suppressing putrefying bacteria and promoting a condition of health. In addition, milk improves the palatability of a mash and thus tends to increase feed consumption. Milk proteins are deficient in glycine and arginine but are good sources of lysine and tryptophan.

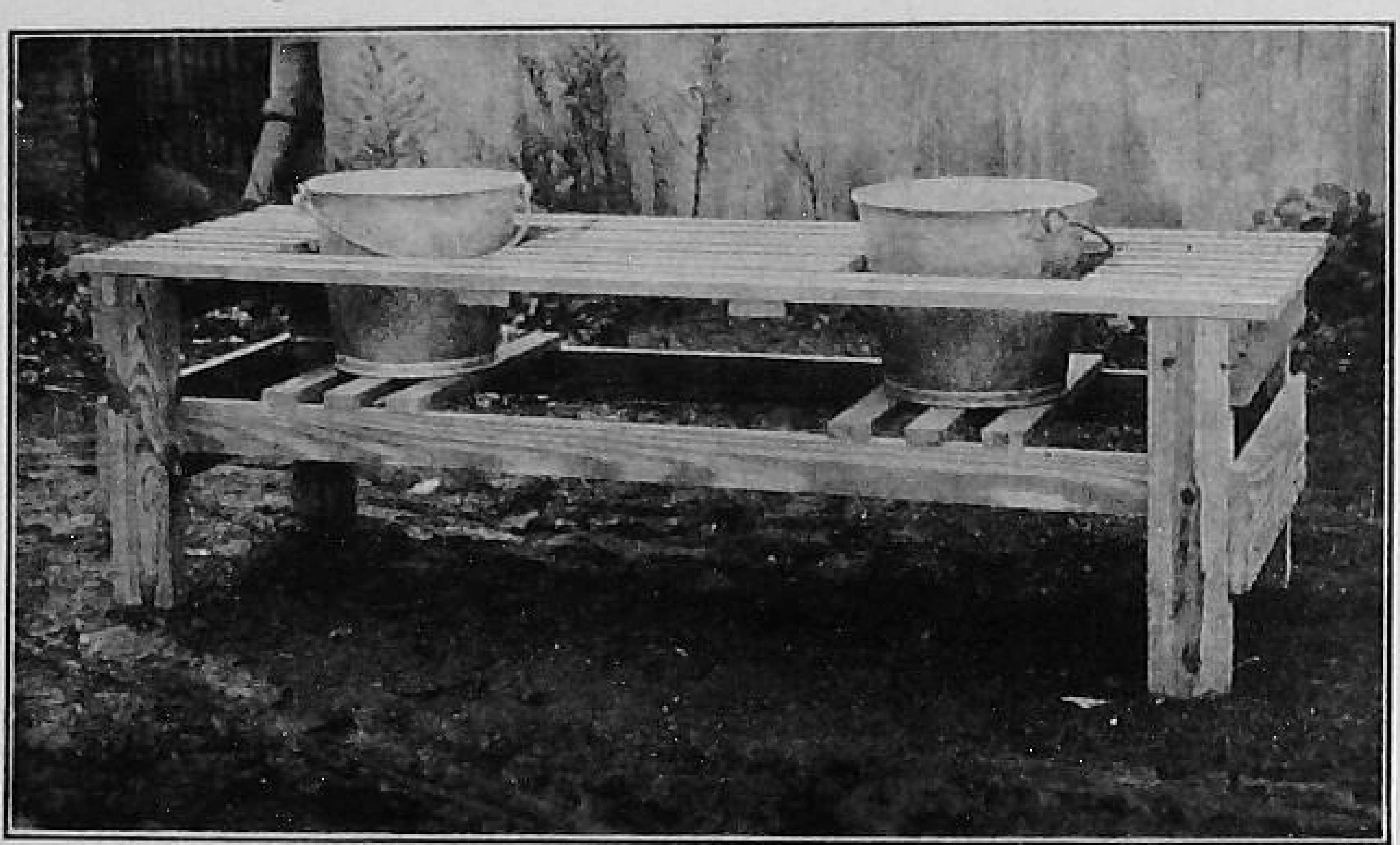


FIG. 162. Plenty of clean water should be available at all times. A slatted platform for water pails keeps the birds from scratching litter into the pails. (*Illinois Agr. Coll.*)

Whole milk is sometimes available on dairy farms but is ordinarily too expensive for most poultrymen to purchase as a protein supplement. When it is available on the premises, it can be used to replace part of the fish meal or meat scrap or both that would ordinarily otherwise be used. Sweet and sour milk have the same feeding value, but it is better to feed one or the other regularly. Since it is difficult to keep milk sweet in hot weather, the regular feeding of sour milk is preferable.

For most poultrymen *skim milk* or *buttermilk* in some form is less expensive than whole milk and is as valuable from the nutritive standpoint. Skim milk and buttermilk are each available in liquid, condensed, and dried form.

It requires about 3 lb. of condensed skim milk per gallon of water to produce a solution equal in feeding value to liquid skim milk. One gallon of liquid skim milk or liquid buttermilk is equal to about 3 lb. of condensed skim milk or condensed buttermilk. One gallon of liquid skim milk or buttermilk is equal to about 1 lb. of dried skim milk or dried

buttermilk. The relative protein feeding value of liquid, condensed, and dried skim milk may be stated as follows:

1 lb. of dried skim milk = about 3 lb. of condensed skim milk
1 lb. of condensed skim milk = about 3 lb. of liquid skim milk
1 lb. of dried skim milk = about 9 to 10 lb. of liquid skim milk

Condensed skim milk and condensed buttermilk each contain not more than 27 per cent of solids, and dried skim milk and dried buttermilk each contain not more than 8 per cent moisture. Different samples of dried buttermilk may vary greatly in their ash content. Liquid skim milk contains about 3.5 per cent protein, condensed skim milk about 12.0 per cent, and dried skim milk about 34 per cent.

TABLE 36. RELATIVE PROTEIN EFFICIENCY OF PROTEIN SUPPLEMENTS
(Wilgus, Norris, and Heuser, 1935)

Protein Supplement	Relative Protein Efficiency
Casein	100
Dried skim milk	100
White fish meal:	
Vacuum dried	104
Steam dried	104
Flame dried	94
Sardine fish meal:	
Domestic	98
Asiatic	91
Menhaden fish meal:	
Steam dried	91
Flame dried	80
Soybean meal:	
Expeller process	89
Hydraulic process	85
Soybeans, ground	58
Meat scrap:	
75 per cent protein	69
60 per cent protein	75
55 per cent protein	82
50 per cent protein	73
45 per cent protein	72
Whale-meat meal:	
70 to 75 per cent protein	73
55 to 60 per cent protein	53
Corn-gluten meal	61

Tankage. Usually under the name of "digester tankage," "feeding tankage," or "meat-meal tankage," this product is prepared from the residue of animal tissues, except for horn, hoof, and stomach contents, by tanking under live steam or by dry rendering. Sometimes the

"stick" or the cooking-water residue and blood meal are added to the tankage to raise the protein content. This is an objectionable practice because both of these added products are relatively low in nutritive value.

Tankage must not contain more than 10 per cent phosphoric acid. If it contains more bone than the amount equivalent to 22 per cent tricalcium phosphate, it must have the name "Bone" included in the brand name. Most of the tankage prepared in recent years has been of lower feeding value than the better grades of meat scrap.

PLANT-PROTEIN SUPPLEMENTS

Plant-protein supplements are usually less expensive than most animal-protein supplements and, for the most part, there is also less variability in composition. When the diet is supplemented mostly with plant-protein supplements, it is necessary to further supplement the diet with certain minerals and vitamins in order to secure satisfactory results in growth and egg production.

Brewers' Grains. This plant-protein supplement consists of about 40 per cent corn grits and 60 per cent barley malt and contains about 25 per cent protein. However, since brewers' grains contain up to about 17 per cent fiber, they can be used only to a limited extent in the poultry diet.

Coconut Oil Meal. This is a by-product in the manufacture of coconut oil and is relatively rich in protein.

Corn-gluten Feed. This is a by-product in the manufacture of cornstarch. The kernels of corn are soaked and separated into hull, germ, starch, and gluten. The hull and the gluten are mixed while still wet, and the mixture is then dried and ground. Corn-gluten feed contains about 23 to 25 per cent protein and when made from yellow corn is also rich in vitamin A.

Corn-gluten Meal. This product consists chiefly of the corn gluten separated in the wet-milling process of starch manufacture with few if any hull fragments. It is about six times as rich in vitamin A as yellow corn and usually has a protein content of 40 to 45 per cent. It is rich in isoleucine but deficient in lysine and tryptophan. The yellow pigments in corn-gluten meal tend to enhance deep-yellow coloring in the skin and shanks of birds, and for this reason it is commonly used in fattening poultry.

Cottonseed Meal. This by-product of the cotton industry usually contains about 41 per cent protein. Cottonseed meal is composed principally of the cottonseed kernel with a proportion of the hull, thus containing considerable fiber. Cottonseed meal is somewhat deficient in lysine.

Although cottonseed meal is a reasonably good source of supplementary

protein for laying hens, their diet should not contain more than about 5 per cent of cottonseed meal or the yolks of eggs produced are apt to become discolored within a few weeks after being placed in storage. The yolks acquire an olive-colored appearance caused by the gossypol contained in cottonseed meal combining with ferric iron released from the yolk proteins. While the eggs are in storage, the iron proteins decompose and thus sufficient iron is liberated to combine with gossypol to produce the iron color. Ferric chloride, in the amount of about 0.5 per cent of the diet, inhibits the absorption of gossypol from the digestive tract.

A processing method has been developed for removing from cottonseed the pigment glands containing gossypol. The gland-free cottonseed meal is superior to commercial cottonseed meal in feeding laying hens because the yolks are not discolored.

Distillers' Dried Grains. The composition of distillers' dried grains varies considerably because of the variation of grain mixtures used, the protein content varying from about 15 to 30 per cent and fiber from about 10 to 15 per cent. Distillers' dried grains are produced after fermentation takes place. They are not used to any appreciable extent in the feeding of poultry although they contain riboflavin and pantothenic acid.

Linseed Oil Meal. This product is obtained from flaxseed after the extraction of linseed oil and is relatively rich in protein except for a deficiency of lysine. Linseed oil meal contains a toxic substance which depresses growth in young chickens. It has been found, however, that wetting linseed meal with about two times its weight in water and allowing the mixture to stand for 18 hr. at 37°C. destroys the toxic principle. Linseed oil meal has laxative tendencies but tends to gum up wet mashes, thus reducing their palatability.

Peanut Meal. This by-product in the manufacture of peanut oil contains about 45 per cent protein, which apparently is of relatively good feeding value, although peanut meal is used to a slight extent. Peanut meal is deficient in cystine, lysine, methionine, and possibly tryptophan.

Soybean Oil Meal. Because the production of soybeans has increased tremendously during the past few years, research pertaining to the utilization of soybean oil meal in poultry diets has been quite intensive. Soybean oil meal is obtained from the manufacture of soybean oil and is a good source of protein.

Three methods are used in processing soybean oil meal: (1) the solvent method, in which the oil is removed by the use of some chemical that dissolves the oil; (2) the hydraulic method, in which the oil is removed by hydraulic pressure; (3) the expeller method, in which the oil is expelled by a friction process which generates heat. The solvent and expeller methods are the ones normally used. Soybean oil meal processed by the

solvent method contains about 45 per cent protein and that produced by the expeller method contains about 42 per cent protein. Overheated soybean oil meal is deficient in certain vitamins and in available cystine and methionine. Raw soybean oil meal contains antitrypsin, which retards growth in chickens. Antitrypsin is readily destroyed by autoclaving for 20 min. at 15 lb.

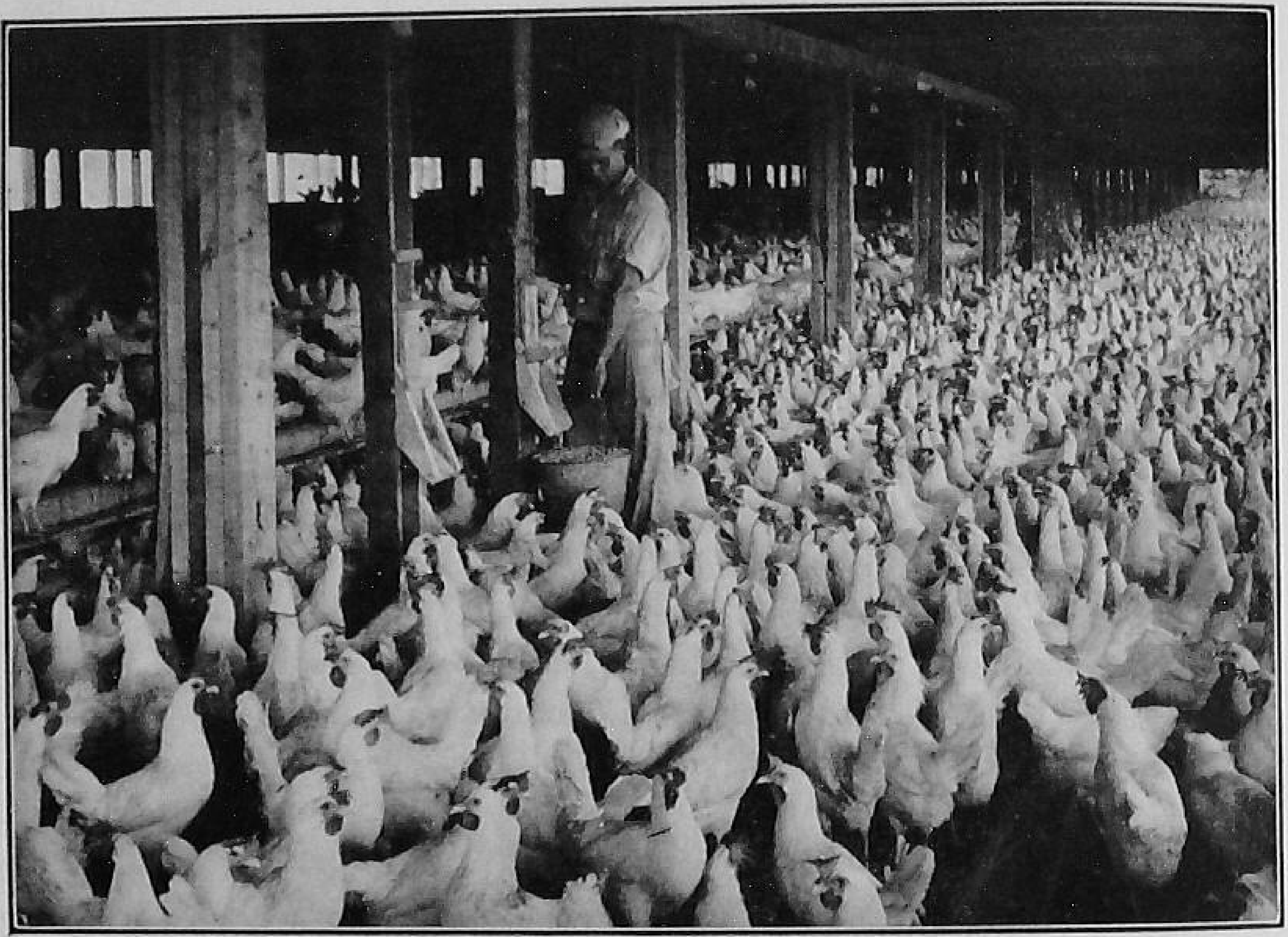


FIG. 163. Scratch grain is obtained from chutes leading from the fourth floor of this four-story laying house, 60 by 360 ft., on the Mack Poultry Farm in Pennsylvania. (*R. C. Baker, Pa. Agr. Ext. Service.*)

Raw soybeans are unpalatable and are not recommended as a poultry feedstuff. When processed properly at the right temperature, however, soybean oil meal is palatable and serves as an excellent plant-protein supplement and, in addition, is relatively economical in price. On the other hand, it is slightly low in methionine and is low in minerals and vitamins.

Sunflower-seed Oil Meal. This is a by-product in the production of oil from sunflower seeds. It is an excellent protein supplement of relatively high biological feeding value.

MINERAL SUPPLEMENTS

Most of the cereal grains and plant-protein supplements are deficient in some minerals that must be fed at certain levels in diets for growing

chickens and laying hens. The dry matter of the fowl's body contains approximately 10 per cent of mineral matter, and the dry matter of the whole egg contains about 35 per cent of mineral matter.

The minerals most liable to be deficient in poultry diets are calcium, phosphorus, manganese, sodium, and chlorine and sometimes iodine.

If most or all of the protein supplements in the diet are of plant origin, the mineral deficiency must be made up by adding certain mineral supplements.

Bone Meal (Steamed). This is a by-product of meat-packing houses and consists of bones which have been cooked thoroughly, then dried and ground. Special steamed bone meal is a by-product in the manufacture of glue or gelatin and contains relatively more calcium and phosphorus than steamed bone meal. Both of these mineral supplements provide growing chickens with calcium and phosphorus for bone development and laying hens with calcium for eggshell formation.

Iodine. In the goiter section of the United States, it is advisable to add iodized salt to the diet unless it contains such marine products as fish meal, fish oil, and oystershells.

Limestone. Calcium carbonate is the main constituent (about 95 per cent) of limestone and provides the laying hen with material for eggshell formation. Dolomite limestone contains enough magnesium to make it objectionable as a mineral supplement because magnesium is antagonistic to calcium assimilation.

Manganese. For the prevention of perosis or slipped tendon in growing chickens, manganese sulfate should be added to the diet at the rate of 4 oz. per ton. Manganese is also necessary for good hatchability.

Mineral Mixtures. Diets that contain no animal-protein supplements are sometimes balanced with respect to their mineral content with a mineral mixture containing several supplements, such as: 50 per cent limestone, 26.97 per cent steamed bone meal, 20 per cent salt (sodium chloride), 2 per cent ferrous sulfate (iron), 1 per cent manganese sulfate, 0.02 per cent potassium iodide (iodine), and 0.01 per cent copper sulfate. If such a mixture is to be added to the mash, the minerals should first be thoroughly mixed and this mineral mixture should then be mixed with a small quantity of mash, after which this mineral-mash mixture should be thoroughly mixed with the total quantity of mash being prepared.

Oystershells. This marine product has been used more extensively than any other product for providing laying hens with calcium carbonate for eggshell formation. Oystershells contain 96 per cent calcium carbonate, and it is advisable to put them in self-feeding hoppers rather than mixing ground oystershell in the mash because hens laying at a high rate

TABLE 37. AVERAGE COMPOSITION IN PER CENT OF INGREDIENTS, EXCEPT VITAMINS COMMONLY USED IN FEEDING CHICKENS
(C. W. Sievert and B. W. Fairbanks, *Feed Bag Red Book*, 1948)

Ingredient	Protein	Fat	Fiber	Ash	Calcium	Phosphorus
Alfalfa leaf meal, dehydrated	20.0	2.0	18.0	10.0	1.9	0.20
Alfalfa leaf meal, sun-cured	18.0	2.0	20.0	10.0	1.9	0.20
Alfalfa meal, dehydrated	15.0	2.0	28.0	8.0	1.4	0.20
Alfalfa meal, sun-cured	14.0	1.5	30.0	8.5	1.20	0.20
Barley	11.5	2.0	6.0	2.9	0.05	0.30
Barley, Pacific Coast	9.0	2.0	5.5	2.5	[a]	[a]
Bone meal, special steamed	6.0	0.5	1.0	82.0	26.0	13.0
Brewers' yeast, dried	45.0	2.5	1.5	7.5	0.05	0.65
Buckwheat	10.0	2.0	10.0	2.0	0.05	0.40
Buttermilk, condensed	10.0	2.0	....	3.5	0.50	0.30
Buttermilk, dry	32.0	5.0	....	10.0	1.30	1.00
Corn, yellow	8.3	3.8	2.0	1.2	0.02	0.25
Corn-gluten meal	41.0	1.5	2.5	1.5	0.10	0.35
Cottonseed meal	43.0	4.0	11.0	5.5	0.25	1.25
Fish meal, menhaden	58.0	6.0	1.0	20.0	7.00	3.50
Fish meal, sardine	65.0	5.0	1.0	15.0	5.00	2.50
Fish solubles, condensed	33.0	3.0	....	[a]	0.10	0.85
Meat and bone scraps	50.0	8.0	2.5	28.0	10.00	5.00
Meat scrap	55.0	8.0	2.5	25.0	8.50	4.25
Molasses, cane	3.0	...	....	9.0	0.50	0.05
Oats	12.0	4.5	11.0	3.5	0.10	0.35
Oats, Pacific Coast	9.0	5.0	11.0	3.5	0.10	0.35
Peanut oil meal	50.0	1.0	8.0	6.0	0.10	0.50
Rye	12.0	1.5	2.5	2.0	0.05	0.35
Skim milk, dry	34.0	0.5	....	8.0	1.30	1.00
Soybean oil meal, expeller	42.0	4.0	6.0	5.5	0.25	0.60
Soybean oil meal, solvent	45.0	0.5	6.0	5.5	0.30	0.60
Tankage	50.0	6.0	2.5	30.0	10.00	5.00
Wheat	12.5	2.0	3.0	2.0	0.05	0.40
Wheat, soft western	10.0	2.0	3.0	2.0	0.05	0.30
Wheat bran	15.0	4.0	10.0	6.0	0.10	1.20
Wheat-flour middlings	16.5	4.5	6.0	3.5	0.10	0.75
Whey, dry	12.0	0.5	....	9.0	0.70	0.70

[a] Values unknown.

naturally require much more calcium carbonate than hens laying at a low rate.

Rock Phosphate (Defluorinated). Raw rock phosphate is not a suitable mineral supplement because it contains fluorine, which is toxic and interferes with the normal assimilation of minerals. Rock phosphate heated to remove the fluorine may be used as a substitute for steamed bone meal.

Salt. Sufficient sodium and chlorine are provided for growing chickens and laying hens if salt is added to the mash at the level of 0.5 to 1 per cent.

VITAMIN SUPPLEMENTS

Although it has been determined that numerous vitamins are required to promote normal growth and bone formation, normal feather development and pigmentation, good egg production, and high hatchability, there are only a few vitamins which are apt to be lacking in sufficient

Fig. 164. Left, a mash hopper on each side of the watering trough extends the length of the 360-ft. pen on the Mack Poultry Farm in Pennsylvania. Right, gathering eggs from a double row of nests is made easy by placing the eggs on a platform supported from a track. (*R. C. Baker, Pa. Agr. Ext. Service.*)

amounts under practical conditions. Diets frequently need to be supplemented with vitamins A and D, and riboflavin. Certain diets high in corn and low in animal products may require additional nicotinic acid, choline, pantothenic acid, and vitamin B_{12}. All the other vitamins are sufficiently abundant in most feedstuffs, as observed in the preceding chapter. Table 38 gives the amount of certain vitamins contained in several feedstuffs that are used as a source of vitamin supplements.

Succulent green grass and alfalfa are excellent sources of carotene, a precursor of vitamin A. When growing birds are reared in confinement and laying hens are kept in confinement, alfalfa meal or alfalfa leaf meal are commonly used as substitutes for pasture. However, the loss of

Table 38. Average Composition of Certain Vitamins Commonly Used in Poultry Feeding
(National Research Council, 1944)

	Vitamin A activity, I.U. per lb.	Riboflavin, mg. per lb.	Pantothenic acid, mg. per lb.	Niacin, mg. per lb.	Thiamine, mg. per lb.
Alfalfa meal, dehydrates	7–242,000	6.73	17.42	[a]	2.0
Alfalfa meal, sun-cured	6–118,000	5.36	12.05	17.70	1.35
Alfalfa leaf meal, dehydrated	15–300,000	9.15	18.0	[a]	4.0
Alfalfa leaf meal, sun-cured	17– 90,000	7.18	12.6	24.1	2.0
Barley	0	0.55	2.84	30.44	2.71
Barley, Pacific Coast	[a]	[a]	[a]	[a]	[a]
Bone meal, special steamed	0	0	0	0	0
Brewers' yeast, dried	0	20.27	59.60	216.70	31.20
Buttermilk, dried	0	15.0	19.80	7.72	1.24
Corn, yellow	1– 4,000	0.6	3.36	6.40	2.06
Corn-gluten meal	2.5– 15,000	0.39	6.26	13.60	[a]
Cottonseed meal	[a]	4.08	6.35	20.40	6.13
Fish meal, menhaden	[a]	2.13	[a]	[a]	[a]
Fish meal, sardine	[a]	3.17	[a]	[a]	[a]
Limestone, high calcium	0	0	0	0	0
Meat scrap	[a]	2.78	3.54	[a]	[a]
Meat and bone scrap	[a]	2.60	[a]	30.53	[a]
Oats	0	0.58	4.50	6.50	3.43
Oats, Pacific Coast	[a]	[a]	[a]	[a]	[a]
Peanut meal	0	2.35	24.10	77.50	3.27
Rice bran	0	1.38	10.33	129.10	10.32
Soybean oil meal, expeller	0	1.87	6.27	17.60	2.62
Soybean oil meal, solvent	0	[a]	[a]	[a]	[a]
Skim milk, dried	0	9.33	15.20	7.31	1.59
Wheat	0	0.51	5.62	26.74	2.10
Wheat, Pacific Coast	[a]	[a]	[a]	[a]	[a]
Wheat bran	0	1.34	11.33	139.97	3.24
Wheat standard middlings	0	0.74	7.10	52.80	7.0
Whey, dried	0	12.92	24.0	8.31	[a]

[a] Indicates data incomplete.

carotene in alfalfa meals is sometimes quite great, due to conditions of curing and storage. Reasonably fresh meals should be used if satisfactory results are to be obtained. Dehydrated meals are usually superior to sun-cured meals. A bright green color is a rough index of high carotene potency in alfalfa meal and alfalfa leaf meal, the latter being preferable because it contains much more vitamin A and riboflavin. For best results, alfalfa leaf meals should contain at least 50 μg. of carotene per gram.

Grass or legume silage, dehydrated pea vines, dehydrated Sudan-grass meal, and vegetable-waste leaf meals from canning plants can be used as substitutes for alfalfa leaf meal. Vitamin A is also supplied by yellow-corn products, fish-liver oils, and vitamins-A-and-D feeding oils.

Birds given access to sunshine usually show no symptoms of vitamin-D deficiency, except possibly during the winter months. When birds are kept in strict confinement, however, mashes should be supplemented with fish-liver oils, vitamins-A-and-D feeding oils or by D-activated animal sterols. High-potency vitamin-D oils are preferred over low-potency oils. If the diet contains ample supplies of vitamin A from yellow corn or other vitamin-A-rich feedstuffs mentioned previously, vitamin D can be supplied by any of the several vitamin-D-activated animal sterols available on the market in dry form.

Some poultrymen use glass substitutes in their brooding and laying houses, since glass substitutes permit the passage of some ultraviolet rays of sunlight, which are excluded by ordinary glass. The amount of ultraviolet light that penetrates glass substitutes naturally depends on their porosity. Those with a wire base usually permit more ultraviolet rays to penetrate than those having a fine mesh, such as cloth materials. Most glass substitutes, however, are not very durable, and the fact that they collect dust lessens their usefulness. Ultraviolet lamps are on the market, but their practical usefulness has still to be demonstrated.

The increased use of plant-protein supplements in poultry mashes in recent years necessitates greater attention to possible deficiencies of riboflavin in the diet. When extra sources of riboflavin are necessary, dried skim milk, dried whey, dried buttermilk, yeast, liver meal, or distillers' or fermentation solubles may be used. Synthetic riboflavin should only be used when it is certain that the diet is properly balanced with respect to all other nutrients.

MISCELLANEOUS FEEDSTUFFS

There are certain feedstuffs that are not used extensively in the feeding of poultry but which are of some value under certain conditions. Several of these miscellaneous feedstuffs are available to poultrymen in certain localities, and their use, therefore, does not have widespread application. Among the various items discussed hereunder, charcoal is not fed for its nutritive value, but since in the past its inclusion in the diet has been recommended, it is included in this discussion.

Acorns. In some localities acorns are available in considerable quantities and apparently ungerminated acorns can be fed up to about 20 per cent of the feed intake. Germinated acorns, however, produce discolored yolks.

Beets and Mangel-wurzels. Since these field products contain about 90 per cent water, they are of practically no value in feeding poultry.

Charcoal. This product is mentioned only because years ago its inclusion in the diet was recommended. As an absorbent it was supposed to have some beneficial effect, but recent experimental work has shown that it should not be included in the diet for any class of poultry. As a matter of fact, its presence in the diet is apt to result in a deficiency of vitamins A, D, K, and riboflavin.

Cow Manure. Cow manure has been shown to contain vitamin-B_{12} activity. Sun-dried and oven-dried cow manures are practically equal in their ability to stimulate growth when added to an all-plant-protein diet. In one experiment, it was found that cow-manure chips obtained from pastures promoted better growth than was obtained from a similar diet without the chips. The eggs produced by hens fed cow manure in the diet contained the chicken-growth factor. Two yolks per kilogram of diet supported growth in chickens at approximately optimal level. The potency of the growth factor is increased following fermentation of the manure. Manure from other animals also contain the chicken-growth factor.

Cow manure also contains an androgenic hormone, which stimulates comb growth. Female chickens require relatively more of the substance to produce a comparable response. Fresh sun-dried manure retained most of its androgenic potency and thus would not be suitable for flock-replacement pullets or for laying hens.

Garbage. Kitchen waste, exclusive of orange and banana peelings, can be fed to growing chickens and laying hens satisfactorily. Much of the material is usually of a carbohydrate material, except for lettuce and other green leaves, which would provide some vitamins. From a practical standpoint, the use of kitchen waste is limited to backyard flocks in towns and villages. One of the most effective ways of using the material is to chop or grind it and mix it with the mash. Garbage obtained from cafés and restaurants may be fed in processed form up to about 10 per cent of the total feed intake.

Greens and Garden Vegetables. Fresh kale, cabbage, lettuce, lawn clippings, and yellow carrots are excellent sources of provitamin A but are high in water content.

Grit. Granite, feldspar, crushed quartz, and phosphate rock are the chief sources of grit that have been used for poultry. Insoluble grit undoubtedly serves in more rapidly crushing kernels of grain in the gizzard than would otherwise be the case, but the results of experiments have demonstrated that it is not necessary to feed grit to growing chickens or laying hens if finely ground, highly digestible diets are fed. Soluble

grit, such as oystershell or limestone grit, may also serve to a lesser extent as a grinding agent as well as supplying calcium.

Molasses. Cane molasses, a by-product in the manufacture of cane sugar, is a good source of energy and pantothenic acid and contains other vitamins and some minerals. It acts as a mild laxative and thus tends to increase the consumption of water. It may be used as a substitute for cereal grains, pound for pound, up to about 2.5 to 4 per cent of the diet.

Potatoes, Irish and Sweet. Raw Irish potatoes are not satisfactory for feeding poultry. Cooked Irish potatoes may be used for growing

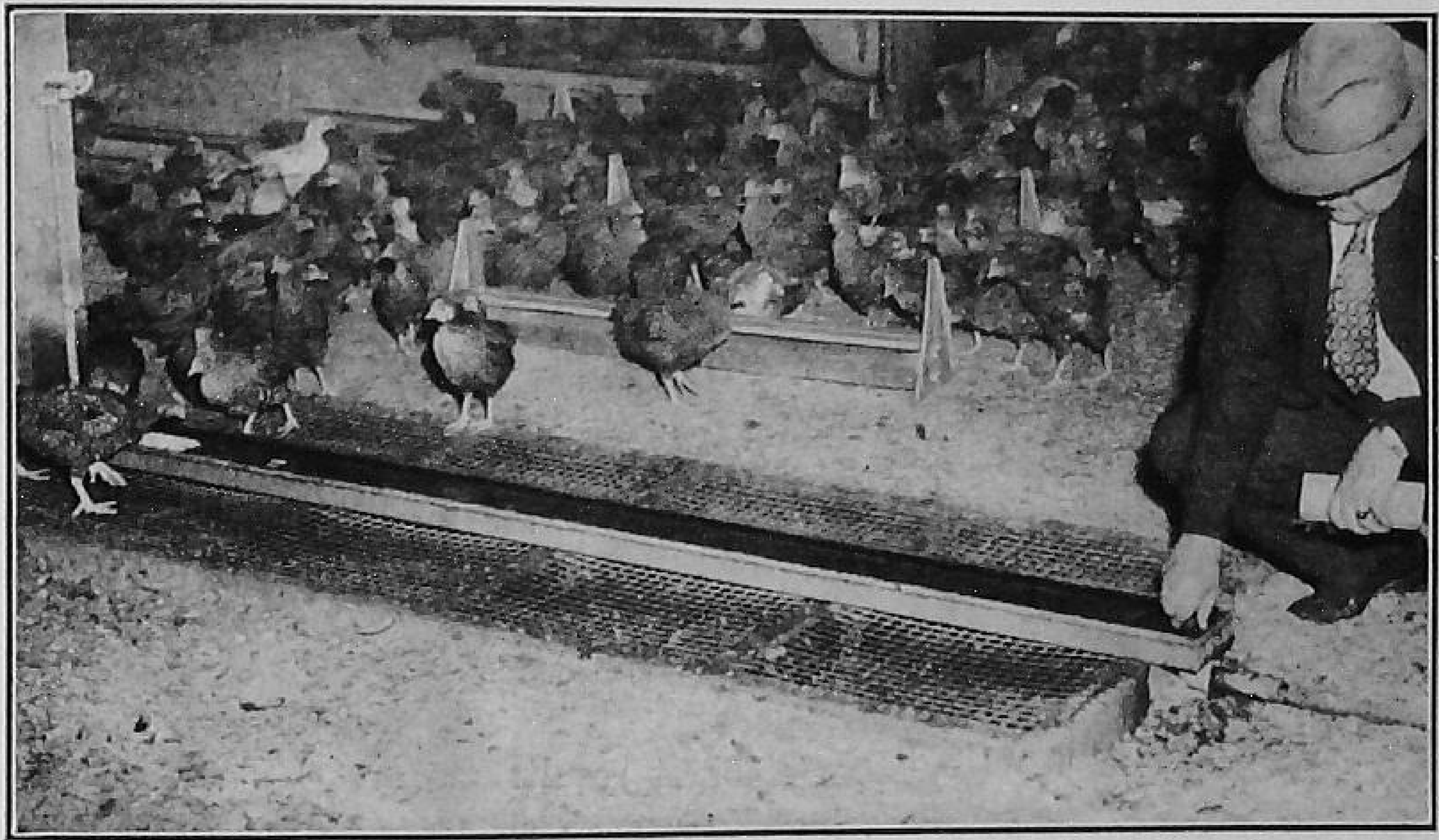


Fig. 165. Note the wire screens on each side of the water trough, this automatic watering system saving much time and labor in providing water. (*G. T. Klein, Mass. Agr. Ext. Service.*)

chickens and laying hens up to a level of about 10 per cent of the feed intake, serving as a substitute for the grain portion of the diet.

Dehydrated sweet-potato meal may be used to replace carbohydrate feeds to the extent of about 10 per cent of the total feed intake.

Silage. Grass, legume, and cereal-grass silages are made by fermenting the fresh feedstuff in a mixture of water and molasses. One ton of silage may be made up of 70 lb. of molasses, 170 lb. of ground grain, and 1,760 lb. of the fresh feedstuff. The mixture should be allowed to stand for several months. It makes a satisfactory feed for growing chickens, laying hens, and breeding stock, in the last case tending to improve hatchability. About 3 lb. per day per 100 hens seems to be a satisfactory level of feeding.

Sprouted Grains. The practice of feeding sprouted grains was rather common many years ago, especially prior to the time that dehydrated green feedstuffs were available. Sprouting appears not to change the feeding value of the grain, and since the labor involved in sprouting the grains and feeding the product is considerable, the practice has been practically discontinued.

Tomato Pumace. This cannery by-product usually consists of a mixture of tomato skins, pulp, and crushed seeds resulting from the processing of tomato juice. Tomato pumace is palatable and contains several vitamins.

Yeast. Although dried yeast is relatively rich in protein, it is too expensive to be used as a source of this nutrient. The protein of yeast has been shown to have approximately the same nutritive value as milk protein. The riboflavin content of yeast is relatively high, but this vitamin can be supplied more cheaply in other feedstuffs.

FACTORS AFFECTING SELECTION OF FEEDSTUFFS

A satisfactory diet is one that is made up of the right kinds of feedstuffs combined in such proportions as to produce the desired results as economically as possible. Under normal conditions, the cost of feed represents one-half or more of the total cost of raising chickens and producing eggs. Therefore, selecting the right kinds of feedstuffs and using them in proper proportions with respect to the nutrients they provide is not only necessary to secure the best results but is also important from the standpoint of economy of production.

In order to secure the most efficient results, however, other factors must be considered in preparing diets, such as the digestibility, palatability, and relative cost of various feedstuffs, the physical condition of mashes, the effect of the diet on the birds, and the effect of the diet on eggs and poultry flesh.

Digestibility of Feedstuffs. Most feedstuffs that are relatively low in fiber are highly digestible. Succulent feedstuffs are probably slightly more digestible than nonsucculent feedstuffs. High heat treatment of certain feedstuffs lowers their digestibility. Mixing feedstuffs tends to increase the digestibility of each of the feedstuffs.

Palatability of Feedstuffs. For the most part, practically all of the commonly used poultry feedstuffs are palatable to chickens. However, some feedstuffs are less palatable than others. Alfalfa meal is less palatable than dehydrated pea vines and succulent green grass. Barley is less palatable than corn, wheat, and oats, especially if the chickens were not fed any barley during the growing period. Rolled oats are preferred to ground or crushed oats. Rye and buckwheat are relatively

unpalatable. Milk products and good-quality animal-protein supplements are relished better than plant-protein supplements. Mashes composed of very finely ground grains are not so palatable as those composed of more coarsely ground grains. Mash mixtures that become sticky when moistened are usually not readily eaten. The feeding of fresh mashes will stimulate increased feed consumption over that of stale mashes.

Color does not seem to be a very important factor in the choice of feedstuffs, although the results of one experiment showed a preference for green-colored feed and green-colored water over feed and water of other colors. In another experiment involving the use of a normal white mash and the same mash colored, respectively, with synthetic red, blue, and orange dyes, the orange-colored mash was consumed in greatest amount, then the blue, the white, and the red in descending order. However, the amount of any particular mash consumed each week varied greatly, there being apparently no consistent preference for any particular colored feed.

Relative Price of Feedstuffs. The price of a feedstuff is influenced greatly by its relative availability. That is why the cereal grains and other carbohydrate feedstuffs so abundantly produced usually cost less than most other feedstuffs. In the corn belt, corn is the most popular cereal used, whereas in the Southwest sorghums are used to replace part of the corn and in many parts of Canada wheat is used extensively. In California and some of the Northern states, barley and wheat are used to a considerable extent because corn is relatively more expensive since the growing season for corn is too short.

Animal-protein supplements usually cost more than plant-protein supplements, but a certain proportion of the former should be used because they supply certain amino acids, minerals, and vitamins in which plant-protein supplements are deficient. The proper proportion of animal-protein supplements to use in diets for growing, laying, and breeding stock is given in Table 40.

The mineral supplements constitute such a relatively small part of the diet that differences in prices among the various mineral supplements are not a very important factor.

Although some of the vitamin supplements are relatively expensive, vitamins A, D, and riboflavin are about the only ones apt to be deficient in practical diets, especially in the case of birds kept in confinement. Fish oil and dehydrated alfalfa leaf meal are among the more important feedstuffs used as a source of vitamin A. D-activated animal sterols, as well as fish oils, are good sources of vitamin D_3. Fermentation solubles, distillers' dried solubles, dried whey, and crystalline riboflavin

are good sources of riboflavin. In some respects, the price of these feedstuffs is a minor consideration from the standpoint of preventing the vitamin deficiencies involved.

With respect to the prices of commercially prepared mashes, it is probably true, in general, that low-priced mashes are poorer in quality than high-priced mashes. Buying a low-priced mash means a lower initial

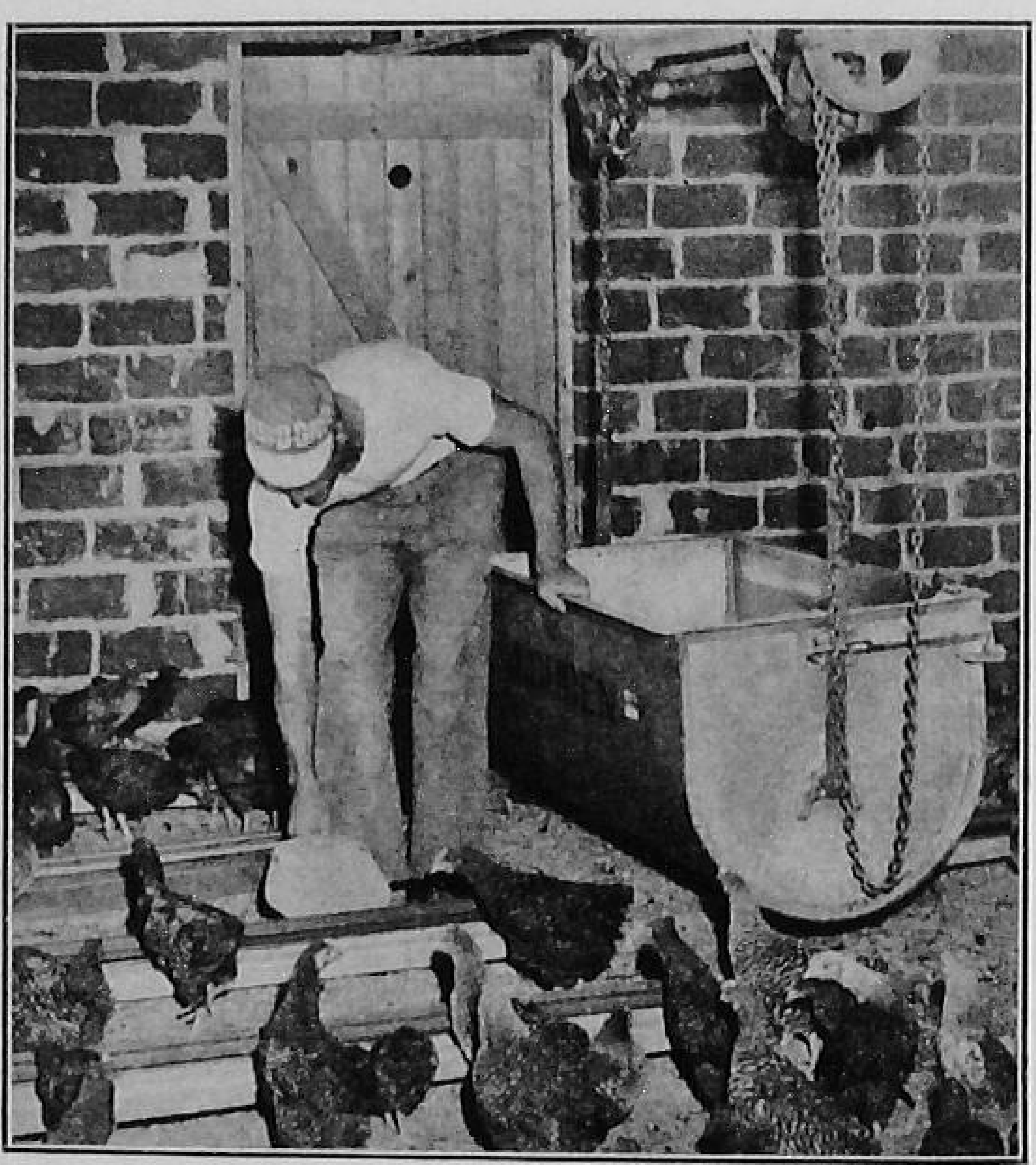


FIG. 166. Where chickens are raised in large numbers, an overhead track for providing feed is a laborsaving factor. (*G. T. Klein, Mass. Agr. Ext. Service.*)

cost of feed but may actually result in a higher cost per pound of chicken meat or dozen eggs produced because of slower growth and lower egg production as compared with buying a relatively high-priced feed.

Effect of Diet on Birds. It has been pointed out several times in previous pages that a well-balanced diet is essential for rapid growth, high egg production, and other desirable characters. Rate of growth is influenced by the amount and quality of protein in the diet. The complete absence of certain vitamins gives rise to severe vitamin-deficiency symptoms. Lack of calcium results in decreased egg production. These are but a few examples that might be cited to emphasize the importance of using a diet properly balanced with respect to the nutrients it contains, the fundamental aspects of which are discussed in detail in previous pages

of this and the preceding chapter. Sometimes, however, diets that are apparently properly balanced produce undesirable effects on the birds. Some examples of such cases are discussed at this time as an aid in the proper selection of various feedstuffs to avoid these difficulties.

Excessive use of cane molasses or linseed oil meal has a laxative effect on the birds. This gives rise to increased water consumption and elimination, thus increasing the moisture content of the litter. An excess of salt in the diet is toxic to chickens and increases water consumption. The minimum lethal single dose of salt appears to be approximately 0.4 per cent of the body weight of growing chickens and adult birds. Diets containing 8 per cent of salt are not necessarily harmful, but, as pointed out previously, from 0.5 to 1 per cent of the total feed intake is sufficient.

Fish meal, meat scrap, cod-liver oil, and soybean oil meal at high levels tend to inhibit the deposition of yellow pigment in the shanks of growing chickens. On the other hand, yellow-corn-gluten meal tends to increase the yellow pigmentation of the shanks.

Effect of Diet on Egg Quality. Most practical poultry diets do not have detrimental effects on egg quality, but if certain feedstuffs are consumed in excessive amounts, egg quality is affected.

With respect to egg size, the results of several experiments indicate that hens fed diets very low in protein produce a relatively larger number of small eggs than hens fed diets with a normal protein content.

Eggshell quality is affected in different ways by diet. Lack of vitamin D in the diet results in a decrease in the amount of lime in the shell, and if the deficiency is of sufficient duration, thin- and soft-shelled eggs are produced. Calcium deficiency in the diet leads to thin-shelled eggs and finally to a cessation of egg production. Manganese is also important for good shell quality.

The feeding of excessive amounts of green feed results in the production of eggs containing a higher proportion of thin albumen to thick albumen than when hens are fed normal amounts of green feed.

Riboflavin in the diet tends to give the albumen a greenish cast, thus indicating a higher nutritive value. The higher the level of riboflavin in the hen's diet, the higher is the riboflavin content of the albumen and yolk up to a certain limit. Some hens apparently produce eggs whose yolks contain a relatively higher concentration of riboflavin concentration than the whites, whereas in the eggs of other hens the reverse is true.

Feeding cottonseed meal produces eggs with a pinkish or olive color after they have been held in storage; the same effect is secured when hens eat a related plant, the common cheeseweed.

Yolk color is significantly affected by certain feedstuffs. Green feed and yellow corn in abundance in the diet give the yolks a dark-yellow

color. Pimiento peppers produce orange-colored yolks, and paprika produces very dark-colored yolks. Olive-colored yolks result from hens eating pennycress, shepherd's-purse, or germinated acorns. The same color of yolk develops in eggs, after being held in storage, laid by hens fed excessive amounts of cottonseed meal, as pointed out previously.

The flavor of eggs is sometimes affected by weeds eaten by hens, garlic and shepherd's-purse having been found to produce strong flavors.

The content of vitamins A, D, riboflavin, and no doubt many other nutrients in eggs is related to the content of these vitamins in the diet. The iron, iodine, and copper content of eggs can be affected by feeding.

Effect of Diet on Poultry Flesh. Diet has little effect on the chemical composition of the poultry flesh, but the percentage of fat in the carcass is increased, of course, as the result of fattening.

During fattening, relatively large quantities of fat and water are deposited in the adipose tissues of the birds. Although the total fat content of the body increases considerably in the case of mature birds on a good fattening diet, the percentage increase in the water content of the edible portions is greater than that of fat. It has also been demonstrated that the vitamin-A content of the livers of chicks that received 0.5 per cent of sardine oil as a supplement to their diet was about four times greater than that of the livers from chicks that received 0.25 per cent of sardine oil. There is a direct correlation between the storage of vitamin A in the livers of chickens and the vitamin-A content of the diet.

On the other hand, it would appear that the protein and fat content of the flesh is not significantly influenced by the protein level of the diet.

Birds fattened on either ground oats or ground wheat have a much lighter colored skin than those fattened on either corn meal or ground barley. Those fattened on corn meal are usually superior in flavor and moisture content of flesh; whereas birds fed on ground wheat are apt to be lacking in flavor.

The hardness or softness of the fat deposited during fattening is influenced by the character of the fattening diet. Cereal grains produce a moderately soft carcass fat. If mutton fat is added to the fattening diet, the carcass fat is inclined to be quite hard, whereas when linseed and certain other oils are added to the diet, the carcass fat is inclined to be very soft.

The color and flavor of the carcass may be affected by diet. It has already been observed that a yellow-corn fattening diet produces a bright-yellow-colored carcass, whereas wheat- and oats-fattened birds have a whitish-colored carcass. Bone char added to the fattening diet in small quantities produces a light-colored skin, regardless of the amount of yellow corn used. Cod- or other fish-liver oils, if fed up to slaughter time,

sometimes produce a "fishy" flavor in the flesh; the oil should not be fed for at least 2 weeks previous to slaughtering.

MASH AND SCRATCH FORMULAS

The previous discussion concerning nutritive requirements for growth, fattening, market-egg production, and hatching-egg production, the nutrients provided by various feedstuffs, and the factors affecting the selection of feedstuffs makes possible the formulation of a diet for any particular purpose. The diet may consist of mash only, or a combination of mash and scratch (whole or cracked grains usually being fed). In either case, it is necessary to use the various feedstuffs in certain proportions in order to secure the proper balance of nutrients for the purpose intended.

Nutritive Ratio. Several years ago the nutritive ratio was considered to be of considerable importance in the preparation of diets, the nutritive ratio being based upon the proportion of digestible carbohydrate and fat (estimated as carbohydrate) to one part digestible crude protein. The nutritive ratio does not take into consideration the mineral elements in the diet, nor does it take cognizance of the vitamins. Moreover, as far as the digestible-protein portion of individual feedstuffs is concerned, any nutritive ratio based on these determinations fails to take into account the fact that the various amino acids in a mixture of feedstuffs may supplement each other in their effects. The newer knowledge of poultry nutrition has largely obliterated any usefulness the nutritive ratio may perhaps have served, except in a very general way.

Nutrient Allowances. The nutritive requirements of growing stock, layers, and breeders have been discussed in the previous chapter. On the basis of these requirements, the nutrient allowances given in Table 39 have been proposed. The allowances provide for margins of safety over the requirements in order to take care of variation in the nutrient content of feedstuffs, variation in feed requirements, and any vitamin destruction that may occur during reasonable periods of storage.

The allowances for vitamin A have been expressed in International units of total vitamin-A activity per pound of feed. This is possible since 0.6 μg. of beta-carotene is equivalent to 1 I.U. of vitamin A. The allowance for vitamin D has been expressed in A.O.A.C. chick units per pound because poultry do not use irradiated ergosterol (D_2) as effectively as do other animals.

Mash Formulas. Keeping in mind the recommended nutrient allowances given in Table 39 and knowing the nutrients contributed by various feedstuffs make it possible to develop formulas for mashes for growing chickens of different ages, laying hens, and breeders. Suggested formulas

are given in Table 40 for growing chickens fed mash only to approximately 8 weeks of age, for growing chickens fed mash and scratch from approximately 9 weeks of age to sexual maturity, for laying birds kept for market-egg production, and for breeders kept for hatching-egg production, the layers and breeders being fed approximately equal parts of mash and scratch.

TABLE 39. RECOMMENDED NUTRIENT ALLOWANCES FOR CHICKENS
(Subcommittee on Poultry Nutrition, National Research Council)

Nutrient	Amount per pound of feed			
	Starting chicks 0 to 8 weeks	Growing chicks 9 to 18 weeks	Laying hens	Breeding hens
Total protein, per cent	20	16	15	15
Vitamins:				
Vitamin-A activity, I.U.[a]	2,000.0	2,000.0	3,300.0	3,300.0
Vitamin D, A.O.A.C. units[b]	180.0	180.0	450.0	450.0
Thiamine, mg	0.9	[c]	[c]	[c]
Riboflavin, mg	1.6	0.9	0.9	1.3
Pantothenic acid, mg	5.0	[c]	2.5	5.0
Nicotinic acid, mg	8.0	[c]	[c]	[c]
Pyridoxine, mg	1.6	[c]	1.6	1.6
Biotin, mg	0.045	[c]	[c]	0.07
Choline, mg	700.0	[c]	[c]	[c]
Minerals:				
Calcium, per cent	1.00	1.00	2.25[d]	2.25[d]
Phosphorus, per cent[e]	0.60	0.60	0.75	0.75
Salt, per cent[f]	0.50	0.50	0.50	0.50
Manganese, mg	25.00	[c]	[c]	15.00
Iodine, mg	0.50	0.50	0.50	0.50

[a] May be fish-oil vitamin A or provitamin A from vegetable sources. The International and U.S.P. unit of vitamin A is 0.0006 mg. (0.6 gamma) of pure beta-carotene.

[b] The A.O.A.C. chick unit of vitamin D is the calcium-depositing efficiency for the chick of a U.S.P. unit of cod-liver oil, the U.S.P. unit being the calcifying activity of 0.025 μg. of calciferol for the rat.

[c] Unknown.

[d] This amount of calcium need not be incorporated in the mixed feed inasmuch as calcium supplements fed free choice are considered as part of the ratio.

[e] Inorganic phosphorus should constitute 0.2 per cent of the total feed.

[f] This figure represents added salt or sodium chloride.

Scratch Formulas. The four most commonly grown grains, yellow corn, wheat, oats, and barley, may be used in various combinations to make up the scratch portion of the diet. Two or three cereals are better than one. The following are a few suggested formulas:

Corn	75	60	50	50	40	50	40
Wheat	25	40	50	25	40	25	40
Oats				25	20	..	10
Barley						25	10

In sections of the country where sorghums are grown, they may be used as a partial substitute for yellow corn. One suggested formula is: yellow corn, 25; milo, 25; kafir, 20; wheat, 20; barley, 10.

TABLE 40. SUGGESTED FORMULAS FOR MASHES, PER CENT COMPOSITION (Subcommittee on Poultry Nutrition, National Research Council)

	Chick starting mash	Chick growing mash (to be fed with scratch)[a]	Laying mash (to be fed with scratch)[a]	Breeder mash (to be fed with scratch)[a]
Ground grains and grain by-products	62.5 to 72.5	68.5 to 78.5	62.5 to 77.5	56 to 68
Minimum animal-protein supplements	3 to 4	3.5 to 4.5	3.5 to 4.5	7 to 9
Additional protein supplements (primarily of vegetable source)	15 to 18	12 to 15	15 to 19	12 to 14
Riboflavin supplements[b]	5 to 8	....	....	5 to 7
Alfalfa meal, dehydrated	2 to 5	4 to 10[c]	4 to 10	4 to 10
Bone meal or defluorinated phosphate (approximate amount)[d]	1	1	2	2
Ground limestone (approximate amount)[e]	1.5	1	2	2
Vitamin-D carrier (when necessary)	?	?	?	?

[a] Mash and scratch.

[b] Potency equivalent to 20 μg. per g. This amount will need to be increased or decreased according to the assay of the supplement used. If milk by-products or liver meal are used, the amount of animal-protein supplements must be reduced accordingly.

[c] When not on good pasture.

[d] Should be increased or decreased to meet the phosphorus specification.

[e] Should be increased or decreased to meet the calcium specification. Oystershell or high-calcium limestone to be fed free choice to laying and breeding hens.

The fiber content of the diet is of some importance because too much fiber tends to reduce the palatability of the diet and retards growth. Very little of the fiber content of the diet is digested by poultry. In the case of broilers, it is essential to feed a diet that promotes rapid growth to marketing time; therefore, the fiber content of the diet should probably be not over about 5 per cent. In the case of chickens raised for flock-replacement purposes, the diet should probably not contain more than

about 6 per cent. Diets for laying hens should not contain more than about 7 per cent of fiber.

METHODS OF FEEDING

The results secured in feeding any class of chickens for any particular purpose depend not only upon the proper balancing of the required nutrients comprising the diet but also upon the method of feeding employed. A well-balanced diet improperly fed will not give the most satisfactory results. Moreover, during recent years many strains of chickens have been bred for more rapid growth and higher egg production, with the result that their nutritional demands are more exacting. Proper methods of feeding are very important, therefore, to enable these better bred birds to utilize the feed as efficiently as possible.

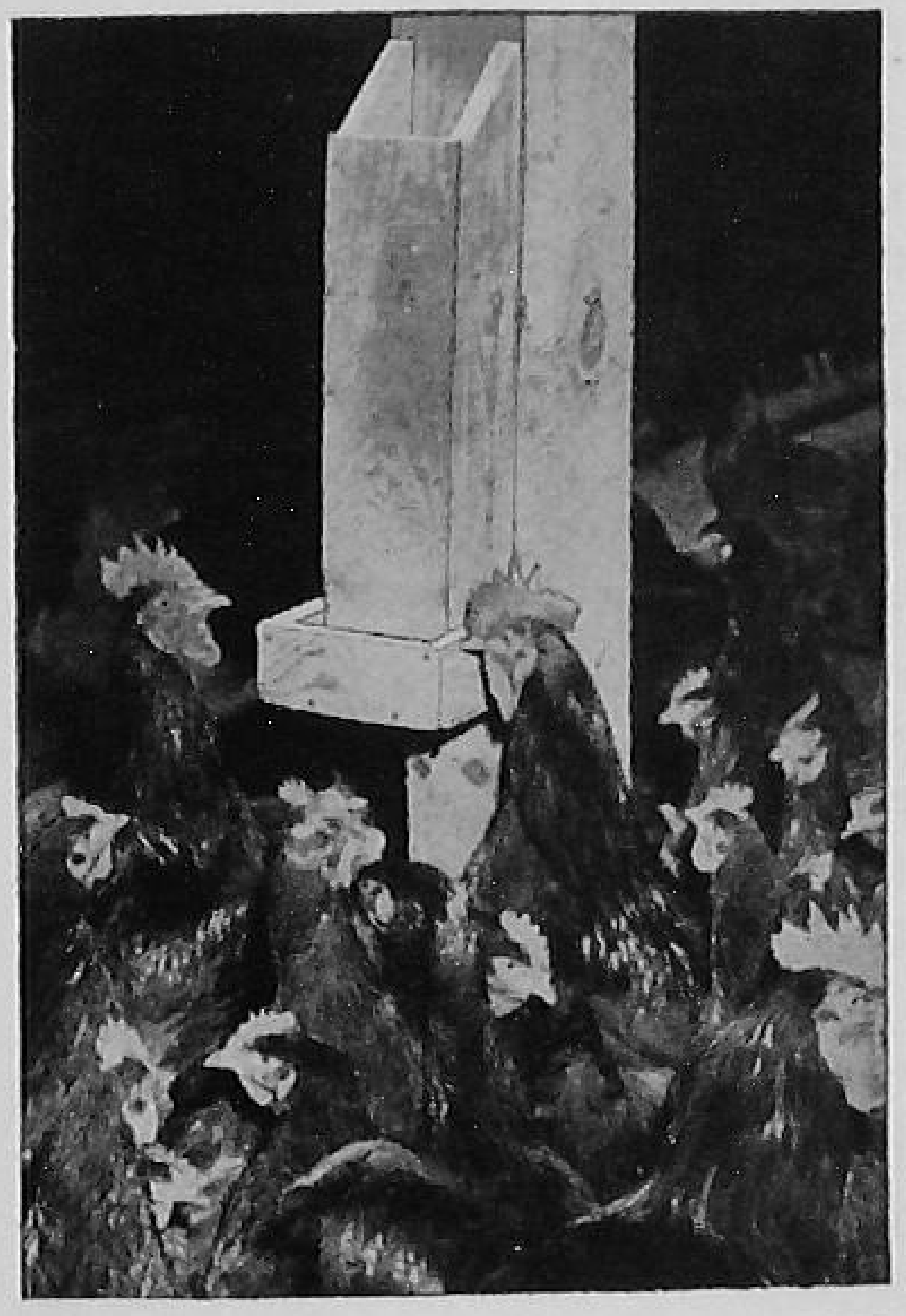
Most poultry-feeding programs include mash, scratch, and minerals. In the case of many flocks, pasture constitutes a part of the poultry diet, but there is an increasing tendency to formulate mashes that provide the materials furnished by pasture and sunshine. The feeding program is more exact for flocks kept in strict confinement than for flocks that have access to sunshine and succulent green pastures.

Free Choice of Single Feeds. Results from various experiments have shown that growing chickens and laying hens will balance their own diets quite well if each individual feedstuff is made available in a self-feeding container or hopper. It has been found, however, that birds differ to some extent in their preferences for certain feedstuffs when fed by this "cafeteria" system. This system eliminates the labor of mixing the feedstuffs into a mash but increases the amount of labor involved in replenishing so many containers, which would necessarily have to be of different sizes. It is not a practical system for most flock owners.

All-scratch Feeding. For years many farmers have relied on whole or cracked grains, usually supplying skim milk, meat scrap, or fish meal as a protein supplement, for growing and laying stock. The newer knowledge of nutrition has demonstrated, however, that such a simple diet could not be expected to yield the most economical returns.

Scratch and a Mash Concentrate. Many farmers who have a variety of home-grown cereals can secure quite satisfactory results with layers by supplementing these whole grains with mash protein concentrates containing 24 to 37 per cent protein, the mash concentrate being fed in self-feeding hoppers. This system eliminates grinding and mixing about 75 per cent of the diet. This method of feeding is used more with laying hens than with young stock. If this system is employed with growing chickens, the cereal grains should be finely cracked for early ages and coarsely cracked after the chickens are about 8 to 10 weeks old.

The higher the percentage of protein in the protein concentrate, the smaller the amount of mash needed to provide the birds with a proper level of protein in the total feed intake. If the scratch portion of the diet is fed in self-feeding hoppers, the layers will pretty well balance their own diet, but the flock owner should make sure that there are no vitamin or mineral deficiencies in the mash.



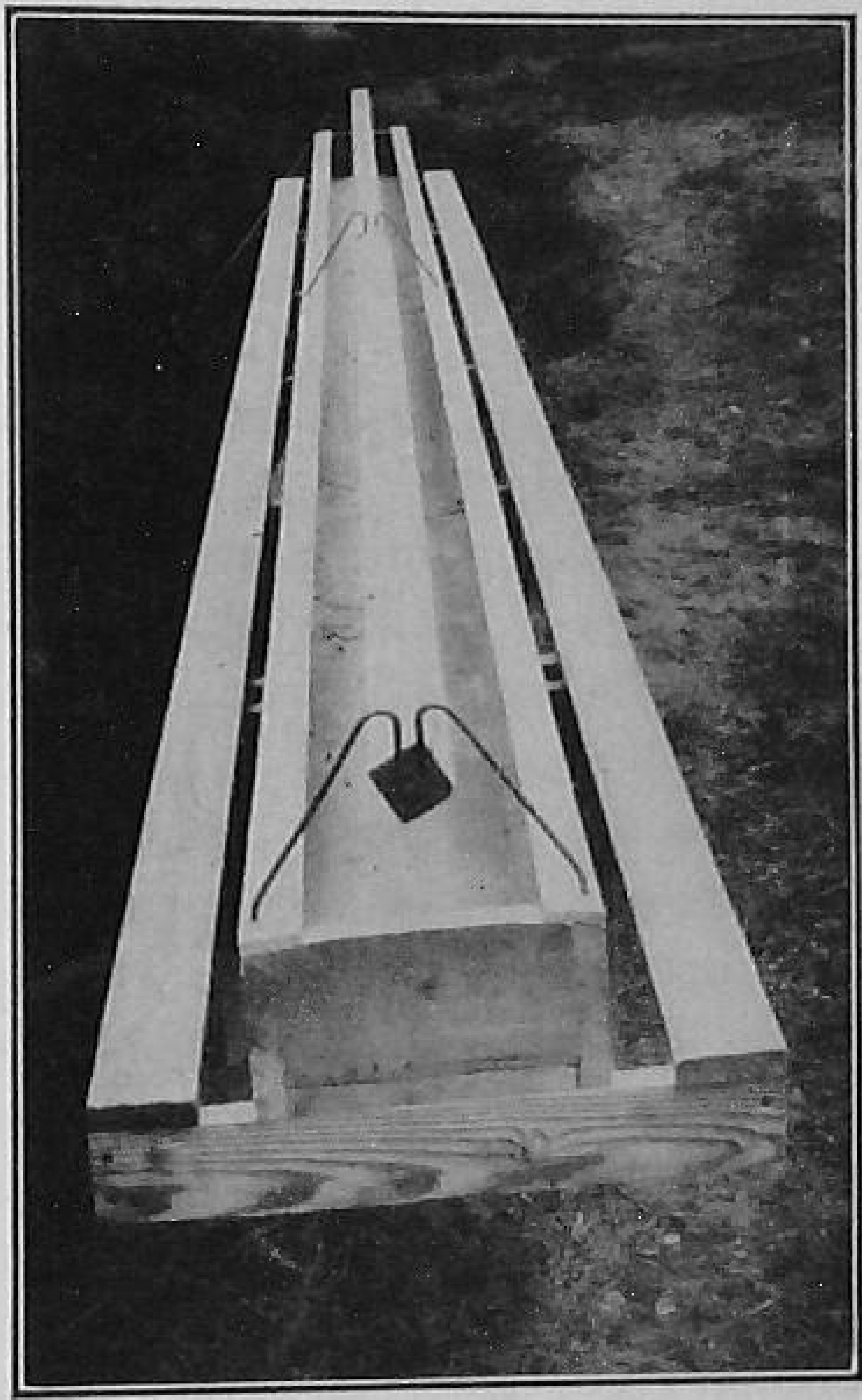


FIG. 167. Left, a special hopper for male breeders, high enough to be out of reach of the females. (*Everybodys Poultry Magazine.*) Right, a reel self-feeding mash hopper for layers. (*Ohio Agr. Exp. Sta.*)

Mash and Scratch. The most popular method of feeding growing chickens and laying hens is to feed mash in self-feeding hoppers and cracked or whole grains in the litter. The mash should contain about 20 per cent protein of good quality.

Growing chickens naturally require mash at the start, but as they grow older should be fed, first, cracked grains in addition to the mash and then, later, they may be fed whole grains. The approximate percentages of mash and scratch according to age is about as follows:

Age, weeks	4	8	12	16
Mash, per cent	100	90	70	50
Scratch, per cent	0	10	30	50

Commercially raised broilers should be fed according to the following percentages:

Age, weeks	4	8	12
Mash, per cent	100	95	85
Scratch, per cent	0	5	15

Laying and breeding hens are usually fed mash in self-feeding hoppers and scratch in the litter or in hoppers, the latter being fed so that the birds will consume approximately equal parts of mash and scratch, except that hens laying heavily will naturally consume relatively more mash than scratch. The scratch grains should be fed in the morning, enough to keep the birds busy for about ½ hr., and again in the evening about 1 hr. before roosting time, giving enough to enable the birds to fill their crops. In some cases, good results have been secured with flocks of inherently high egg-laying ability by feeding the scratch portion of the diet in self-feeding hoppers.

Some flock owners interested in keeping their flocks at a high level of egg production make a practice of sprinkling moistened mash on top of the dry mash in hoppers. This is usually done at about noon or about midafternoon. Mash moistened with skim milk is more palatable than mash moistened with water. Other flock owners use pellets instead of moistened mash to stimulate increased feed consumption and avoid a loss in body weight, which sometimes results in decreased egg production.

Dry Mash Only. This is a simple laborsaving method of feeding that should give reasonably good results if a satisfactory mash mixture is used. This is the usual method of feeding laying hens kept in laying cages. The all-mash method is naturally used during the first few weeks for growing chickens and almost up to marketing time in the case of broilers. It should be kept in mind, however, especially in feeding laying and breeding stock, that mashes do not retain their nutritional value, especially certain vitamins, as long as do whole grains.

Wet Mash. As mentioned previously, wet or moistened mash is sometimes sprinkled on top of dry mash for layers to increase feed consumption. For backyard or other small-sized flocks, wet-mash feeding would probably be justified, especially if fresh garbage and garden wastes were cooked and fed with the wet mash. Wet-mash feeding is the regular practice employed in fattening poultry for market. Care should be taken not to feed too much wet mash at any one time, since what is left over may become sour and moldy, especially in warm weather. Reasonable care should be taken to keep the feed troughs clean.

Pellets. Dry mash is compressed under high pressure into cylindrical pellets of different sizes for young stock and layers. Pellet feeding, therefore, is a modification of dry-mash feeding. Feeding pellets to birds on range reduces feed wastage from wind as compared with feeding dry mash. There is liable to be some wastage of pellets fed to layers kept in cages. The practice of sprinkling pellets on top of dry mash fed in self-feeding hoppers has increased during recent years, both in the case of growing chickens and layers. Satisfactory results have been secured in growth and egg production by feeding pellets in self-feeding hoppers instead of dry mash.

Crumbles. Large-sized pellets, after being cooled, are passed through burr mills, granulators, or rolling mills, which break up the pellets into crumbles of varying sizes. They are apparently quite palatable. When used extensively, however, they have been reported to induce cannibalism among the birds.

FEEDING YOUNG STOCK

As soon as baby chicks are ready for the brooder, they should be provided with feed and water. For the first few days the starting mash should be placed on egg-case flats, rough cardboard paper, or in shallow feed troughs near the edge of the brooder. As soon as the chickens are old enough, the starting mash should be placed in self-feeding hoppers equipped with reels, ½-in.-mesh hardware cloth being laid on top of the mash to prevent the chickens from wasting the feed. When the chicks are about 4 weeks old, 1-in. hardware cloth should be used. Cracked wheat or finely cracked corn or both may be fed beginning about the fourth week. By the time the chickens are about 4 weeks old, whole wheat and coarsely cracked corn may be fed. This scratch portion of the diet may be scattered in the litter or placed in self-feeding hoppers.

An adequate supply of water is necessary throughout the growing period. The daily requirement is about as follows: during the first 2 weeks, 1 qt. per 30 birds; from 3 to 6 weeks, 1 qt. per 15 birds; from 7 to 10 weeks, 1 qt. per 8 birds; and after the tenth week, 1 qt. per 6 birds.

Feeding Broilers. If broilers are being produced, it is desirable to feed them starting mash for the first 6 weeks, during which time the protein content of the total feed intake should be about 20 per cent. This is important in order to secure rapid growth. As a matter of fact, for the rest of the period in growing broilers to market age, rapid growth is very important because, for the most part, the faster the growth the fewer the number of pounds of feed consumed per pound of gain in weight. Beginning the seventh week cracked grains may be fed as scratch, giving relatively small feedings in the morning and evening at the start and

gradually increasing the proportions, especially in the evening. Providing artificial lighting to give a 14-hr. "feeding" day tends to increase the amount of feed consumed and thereby induces faster growing. Mashes containing high levels of cod-liver oil, or other fish oils, should not be fed during the 2 weeks prior to marketing time.

Some broiler producers feed a diet relatively high in energy content, using as much as 65 per cent yellow corn, and in addition to soybean oil

FIG. 168. A lime spreader used on the farm of George Parker in New Jersey to feed scratch grain to growing chickens on range. One-half of the 120-acre farm, divided into four fields, provides clean range each year for the young stock. (*N.J. Dept. Agr.*)

meal about 20 per cent animal-protein supplements, including fish meal, liver meal, and meat and bone scrap. The fiber content is quite low. Since corn is deficient in nicotinic acid, this "high-energy" diet must be supplemented with a certain amount of nicotinic acid, and it is advisable to supplement the diet with choline. This kind of a diet promotes rapid growth and is therefore claimed to be an efficient diet for broiler production.

Feeding Pullets. Pullets reared for flock-replacement purposes will grow more uniformly if they are separated from the cockerels at about 8 weeks of age. The cockerels, except those needed for breeding purposes, could be sold at from about 12 to about 16 weeks of age, depending upon

the price of feed and the market price of broilers, fryers, and small roasters.

The pullets should be fed a diet containing about 15 to 16 per cent protein. A satisfactory diet for properly developing the pullets consists of a growing mash containing about 20 per cent protein and scratch fed in amounts equal to the daily consumption of mash; this gives about a 16 per cent protein diet. Farmers who have ample supplies of home-grown grains could feed a mash concentrate containing 24 to 32 per cent protein but should feed more scratch grain daily than when a growing mash is fed.

Good range which provides an abundance of succulent green feed is very desirable. Oystershell or limestone grit should be available in separate hoppers.

Growth and Feed Consumed. Males grow faster and consume more feed than females, and chickens of the general-purpose breeds grow faster and consume more feed than Leghorn chickens. Crossbred chicks usually grow faster than purebred chickens during the first 10 or 12 weeks and utilize feed more efficiently. Chickens reared in confinement usually grow faster and consume more feed than the same kind of chickens reared on range.

TABLE 41. APPROXIMATE AVERAGE WEIGHT IN POUNDS PER MALE AND FEMALE CHICKENS AT 2-WEEK INTERVALS

Age, weeks	White Leghorns		General-purpose breeds	
	Males	Females	Males	Females
0	0.09	0.09	0.09	0.09
2	0.25	0.22	0.27	0.24
4	0.54	0.44	0.61	0.52
6	1.08	0.90	1.34	1.06
8	1.61	1.27	2.23	1.71
10	2.20	1.73	3.18	2.40
12	2.68	2.14	3.72	2.93
14	3.12	2.49	4.08	3.21
16	3.44	2.70	4.41	3.49
18	3.67	3.02	4.80	3.86
20	3.99	3.37	5.33	4.24
22	4.36	3.62	5.72	4.45
24	4.62	3.85	6.03	4.67

The data in Table 41 give the approximate average weight in pounds per bird of cockerels and pullets in White Leghorns and general-purpose breeds, respectively, from hatching time to the end of each 2-week period

up to the end of the twenty-fourth week. The data in Table 41 are intended to serve merely as an index of weights of males and females that might be expected to be attained in the average flock. It must be kept in mind that the rate of growth is influenced to a considerable extent by at least four factors: (1) the inherent adult size of the birds of a particular strain of any breed or variety; (2) the amount of feed consumed from day to day, which is influenced to some extent by the kind of diet; (3) the protein nutritional adequacy of the diet; (4) methods of management, especially as to whether the birds are reared on range or are kept in confinement on the floor of the house or in batteries.

Table 42. Approximate Average Amount of Feed Required per Pound of Live Body Weight at Different Ages in Relation to Average Amount of Feed Consumed per Bird and Average Live Body Weight per Bird, Both Sexes in Approximately Equal Numbers, Reared on Range

Weeks	White Leghorns			General-purpose breeds		
	Average weight per bird, lb.	Average amount of feed consumed per bird, lb.	Average amount of feed per pound of live weight, lb.	Average weight per bird, lb.	Average amount of feed consumed per bird, lb.	Average amount of feed per pound of live weight, lb.
4	0.49	1.15	2.87	0.56	1.30	2.77
8	1.44	4.00	2.96	1.97	5.50	2.93
12	2.41	8.00	3.45	3.32	10.50	3.25
16	3.07	13.00	4.37	3.95	16.00	4.14
20	3.68	18.00	5.01	4.78	22.00	4.69
24	4.23	24.00	5.79	5.35	28.00	5.23

Concerning the amount of feed required to raise a certain number of chickens to market age or until the pullets are ready to be placed in the laying house, the data presented in Table 42 may be used as a guide. Since White Leghorn chickens do not grow so fast as chickens of the general-purpose breeds, and consume relatively less feed, the data pertaining to these two classes of chickens are presented separately. The data given in Table 42 show not only the approximate number of pounds of feed required for different periods but also the number of pounds of feed required per pound of gain in weight as the chickens increase in size.

The data given in Table 42 pertain, for the most part, to flocks of chickens reared on range. The amount of grain consumed by chickens grown on grass or other good range is somewhat less than in the case of chickens kept in strict confinement.

On the basis of the data given in Table 42, it is possible to determine the approximate amount of feed required by a certain number of chickens up to a certain age. To raise 100 chickens on range, approximately the same number of each sex, would require approximately the following pounds of feed, in round numbers:

Periods, weeks	White Leghorns	General-purpose breeds
To 4	110 to 140	115 to 145
To 8	370 to 430	520 to 580
To 12	770 to 830	950 to 1,150
To 16	1,200 to 1,400	1,500 to 1,700
To 20	1,650 to 1,950	2,000 to 2,400
To 24	2,200 to 2,600	2,600 to 3,000

The amount of feed required per 100 birds of any particular strain depends upon the breeding of the strain and whether the birds are reared in confinement or on range, as well as on the particular method of feeding practiced. When pullets only are raised, somewhat less feed is required than when approximately equal numbers of both sexes are raised together.

FATTENING CHICKENS

Birds that are fed special fattening diets before being marketed include fryers, roasters, capons, sometimes broilers, and laying hens that have outlived their usefulness as layers. In the case of young birds fed a special fattening diet, much of the increase in body weight is due to the growth of various tissues, but there is also a considerable amount of deposition of fat, if a good fattening diet is used. Hens are frequently fat enough without being fed a fattening diet; but if they happen to be thin in flesh, a short period of fattening will prove profitable. The birds may be fattened in pens or in specially designed fattening batteries. As a matter of fact, very little fattening of poultry is now done on the farm, since most of the commercially dressed poultry is fattened in feeding stations operated by the various packing-house companies. Before being placed in the batteries, the chickens should be carefully graded for condition and finish, because some birds will need to be fattened for a longer period than others.

Finishing Broilers. The finished appearance and market grade of broilers can be improved by feeding a finishing diet during the last 10 days or 2 weeks prior to marketing time. Some samples of fish meal and meat scrap as well as low-potency cod-liver oils tend to decrease the amount of yellow color in the legs. Feeding plenty of yellow corn during

the finishing period increases yellow pigmentation. Some broiler producers add 10 to 20 per cent yellow-corn-gluten meal to the mash during the finishing period to increase the yellow pigmentation of the shanks. Pellets are used by some broiler producers.

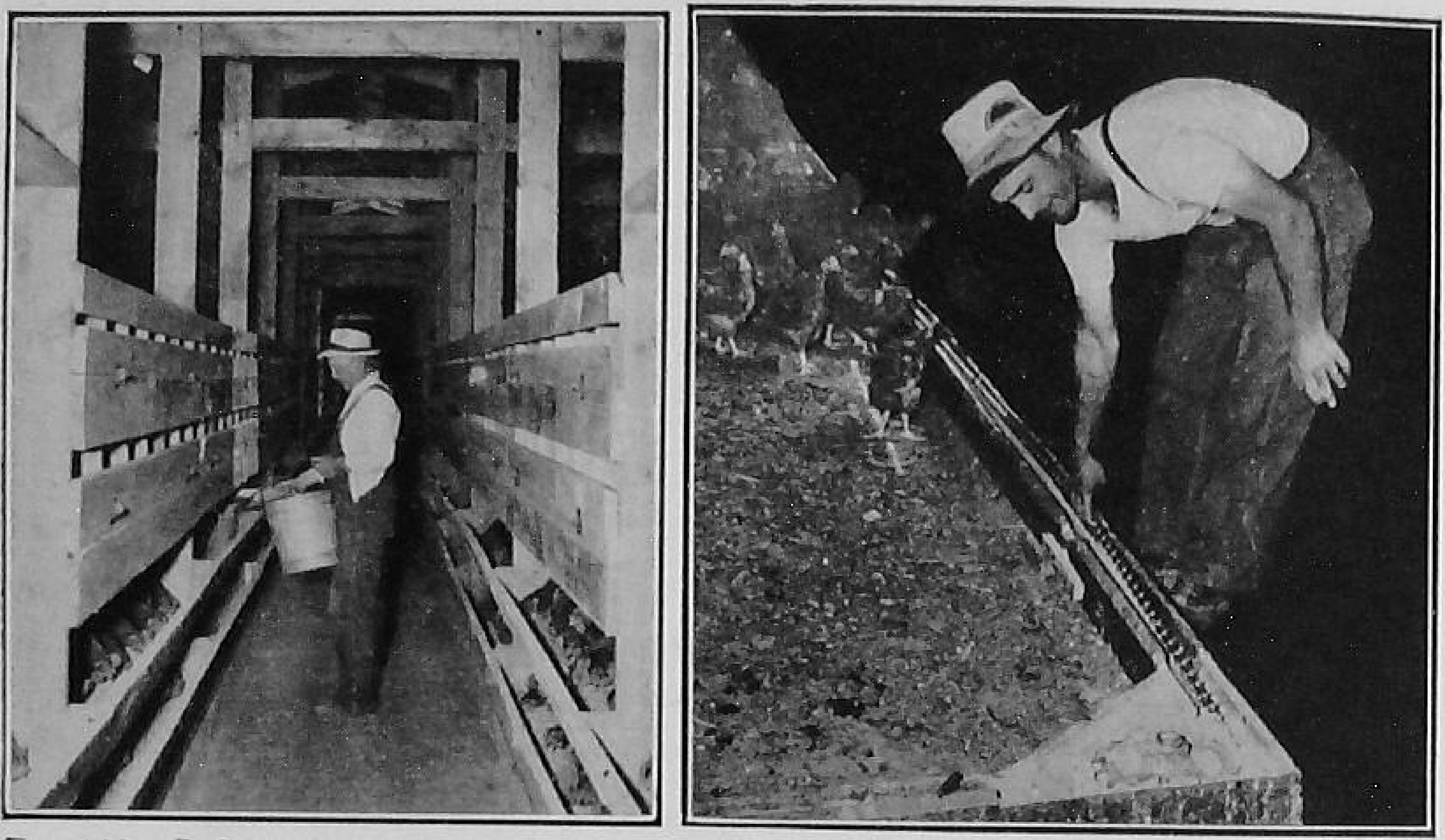


FIG. 169. Left, two rows of nests above two levels of feed hoppers enable this Georgia egg producer to manage 5,000 layers. The laying house is 44 by 410 ft., and the roof, ends, and sides are aluminum. (*University of Georgia and Everybodys Poultry Magazine.*) Right, a mechanically operated automatic feeder saves much time in feeding broilers. (*Md. Univ. Ext. Service.*)

Fattening Fryers, Roasters, and Capons. The results secured in the fattening of poultry depend not only upon the age and condition of the birds when they are placed in the fattening batteries but also upon the kind of diet fed and the method of feeding. The birds should be sorted carefully according to size and condition. The fattening period should be continued as long as economical gains in weight are being made, the period usually extending from about 7 to about 14 days.

The fattening diet should be of such consistency that it will pour readily into the V-shaped trough. The proper consistency is usually obtained when about 60 per cent of water is added to the mash mixture.

While the birds are being fattened, they should be kept as quiet as possible at all times. The temperature of the fattening room should be kept as even as possible, particular care being taken to avoid excessively high temperatures. Under carefully controlled conditions in fattening establishments, feeding relatively small amounts of feed three to five times daily will produce greater gains than feeding twice daily. Because of the problem of the amount of labor involved, however, it is customary to give three feedings daily.

Ground cereal grains usually make up 75 per cent or more of the fattening diet. Yellow corn is apparently superior to other cereals in producing fat. Wheat apparently is superior to oats and barley, although hulled oats are superior to wheat. Buckwheat is a relatively efficient producer of fat but is not used extensively. A combination of these cereals, with yellow corn predominating, is probably the best kind of a fattening diet from the standpoint of gains in weight and increase in fat deposition. The mash mixture is better when moistened with skim milk, buttermilk, or whey, the first of these three ingredients being the best. Any one of the three increases the palatability of the mash and, therefore, induces increased feed consumption and greater gains. In commercial-poultry-dressing plants, pellets are used extensively for fattening. Water should be provided between feedings.

Using Drugs Having Hormone Effects. The amount of fat in the tissues of young birds can be increased considerably by using certain synthetic drugs having hormone effects. Also, in old males fat deposition is increased and the flesh is more tender.

Pellets of diethylstilbestrol, a synthetic drug having the same effect as estrogen or the female sex hormone, implanted in the neck region has proved to be quite effective in increasing the amount of fat deposited in the breast muscle and in other parts. A few weeks' treatment is necessary for the most effective results. Pellet implantation is the only method so far officially approved by Federal government authorities.

Other synthetic drugs having hormone effects have been used experimentally in very small amounts in the diet. Dianisylhexene has been used for fattening broilers, fryers, and roasters. It is dissolved in feeding oil at the rate of 40 to 50 mg. per lb. of oil, 1 lb. of the oil being used per 100 lb. of the fattening diet. When fed to cockerels, their combs and wattles shrink and become pale in color but considerable fat is added to the tissues. Significant results are sometimes secured in 2 or 3 weeks of feeding.

In one experiment with Single-comb White Leghorns 8 to 12 weeks old, it was found that lower dosages of synthetic estrogens with longer treatments were superior for fattening to higher dosages with shorter periods. Older birds used estrogens more efficiently than did younger birds. It was found that dienestrol diacetate and dianisylhexene administered orally were equally potent lipogenous agents on a weight-for-weight basis.

Interesting results were secured in an experiment with White Plymouth Rocks treated between the sixth and twelfth weeks of age. One group served as controls; a second group was fed diets containing 0.2 per cent thiouracil, a thyroid-depressing drug, a third group was given stilbestrol-

pellet implants containing 14 mg. per pellet; a fourth group was given a combination of thiouracil and stilbestrol. Feeding thiouracil alone resulted in depressed growth, but in the other treated groups, growth was significantly greater than in the control group. The percentage of fat in the dressed birds was as follows: control, 9.5; thiouracil, 19.9; stilbestrol, 17.4; thiouracil-stilbestrol, 25.3.

The results of a 4-week experiment with New Hampshire cockerels ranging from 11 to 13 weeks of age, indicated than an optimum degree of hypothyroidism for growth and fattening was attained when 1 g. of thyroprotein (iodinated casein) per 100 lb. of feed was added to a diet containing 0.2 per cent thiouracil. Not only was rate of growth greater than among birds fed a "control" diet without thiouracil and thyroprotein, but the market grade of the treated birds was improved. The addition of 3, 5, and 7 g., respectively, of thyroprotein to the diet containing 0.2 per cent thiouracil resulted successively in decreasing market grade as compared with the market grade of birds fed a diet containing 0.2 per cent thiouracil and 1 g. of thyroprotein per 100 lb. of feed.

FEEDING LAYING STOCK

Pullets moved from the range to the laying house need to be handled carefully and for the first few days should be given ample supplies of succulent green feed if the pullets are to be kept confined. Laying birds are sensitive to sudden changes in feeding and management. When the pullets are first placed in the laying house, feed consumption is apt to decline unless precautions are taken, such as feeding plenty of green feed and sprinkling pellets or crumbly mash over the dry mash in the hoppers. A regular feeding schedule from the time the pullets are housed is very important.

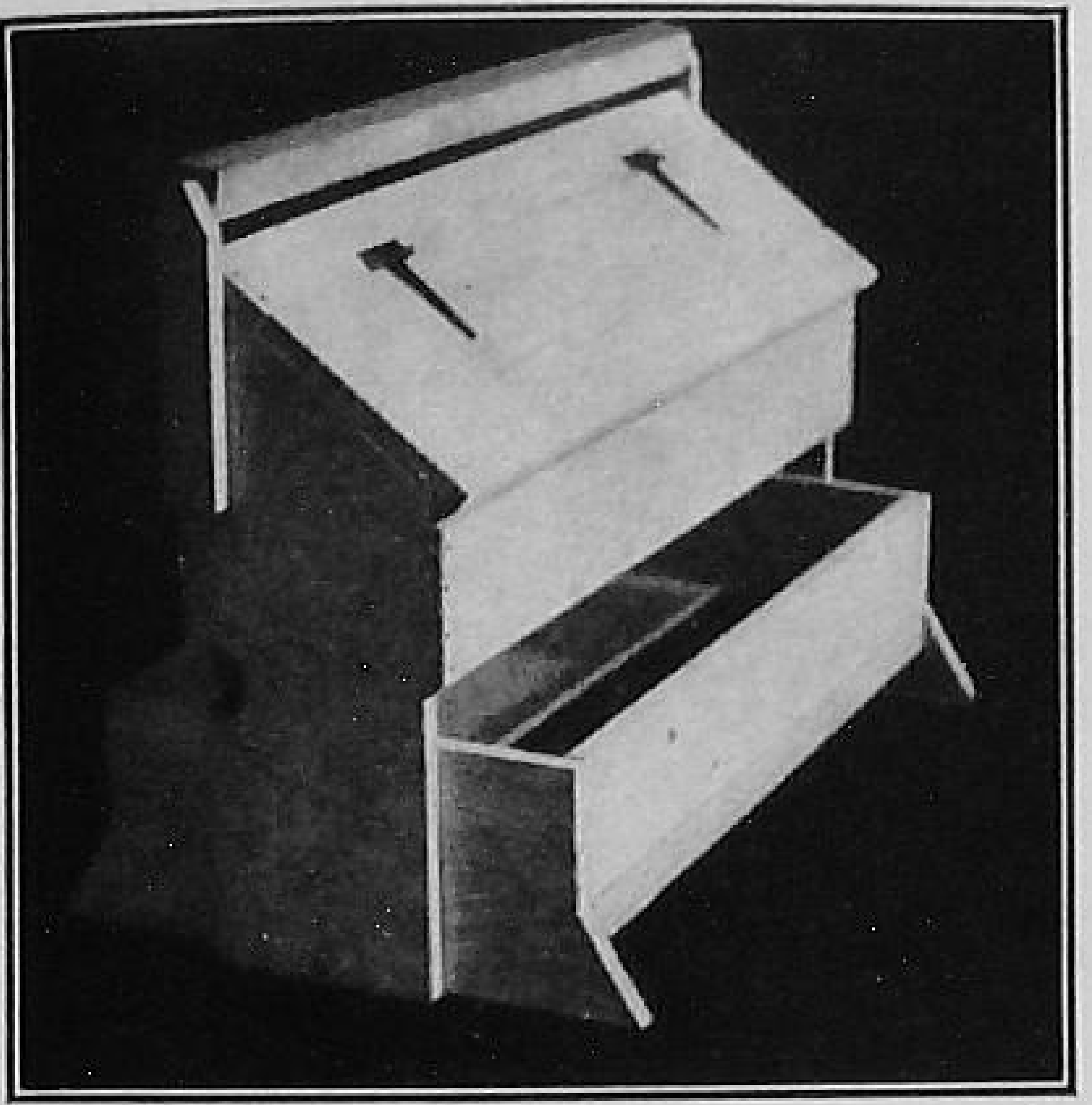
In most cases scratch is fed in addition to mash, the birds being fed so that they consume approximately equal parts of mash and scratch. The scratch portion of the diet should consist of a mixture of at least two, and preferably three, of the staple cereals, corn, wheat, oats, and barley. When the level of egg production is at its peak, the birds will consume about 60 per cent mash and about 40 per cent scratch.

Every precaution must be taken to prevent a slump in feed consumption, especially during the summer months, because a decrease in body weight and consequently lowered egg production are the usual results. Sprinkling moistened mash or pellets over the dry mash about noon helps to stimulate feed consumption. Feeding fresh green feed at the rate of 4 lb. per 100 birds is a good practice.

Forcing the molt through feeding is not recommended.

Oystershell or limestone grit should be available at all times in self-feeding hoppers.

Ample supplies of fresh water should be available at all times, the daily requirements of 100 layers being about 6 gal., allowing for some wastage. Automatic water fountains save much time and labor in providing water. Care should be taken in winter to prevent the water from freezing.



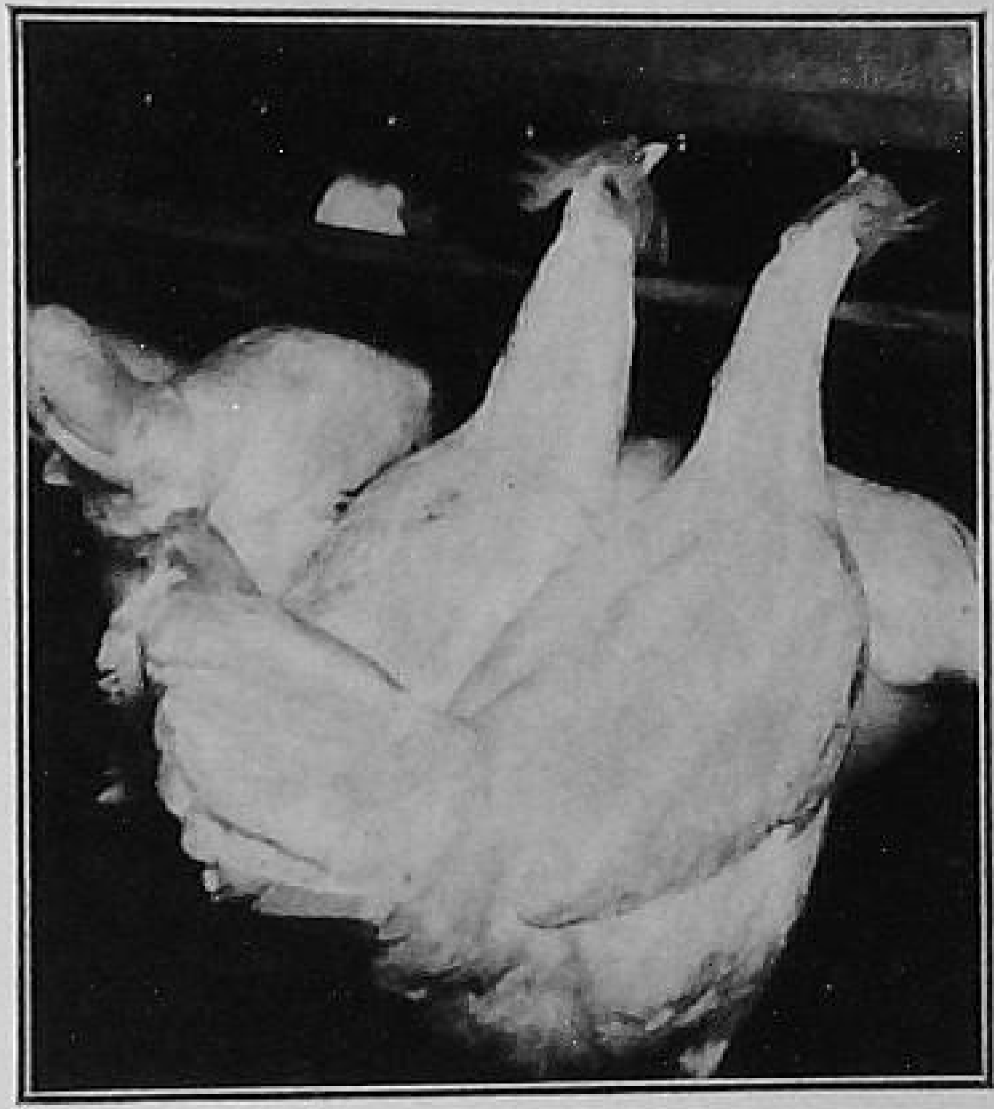


Fig. 170. Left, a self-feeding green-feed hopper. Right, overhead-valve drinking fountain. (*Dryden Poultry Breeding Farm.*)

Feeding Broody Hens. Broodiness is more of a problem in general-purpose breeds than in Leghorns. In any flock, however, broodiness lowers the level of egg production. The more frequently that hens become broody and the longer they remain broody, the greater the decrease in egg production. Egg production is resumed relatively soon if broodiness is interrupted immediately. The most effective way of accomplishing this is to remove each broody hen from the nest as soon as she shows signs of broodiness and confine her to a coop with a slat or wire bottom and provide her with plenty of feed and water. Moist mash is preferable to dry mash and is especially preferable to whole grain. The sooner that broodiness is broken up, the sooner egg production is resumed.

Using Artificial Lighting. Providing artificial lighting in the laying house during the fall and winter months to give the birds a 13-hr. working day tends to increase the fall and early winter egg production of pullets and maintain good egg production among yearling hens. For best results, pullets of different ages should be kept in separate pens and the yearlings should be kept by themselves.

Light is usually provided by 40-watt Mazda lamps, each equipped with a cone-shaped reflector 16 in. in diameter at the base and 4 in. high.

Each lamp will provide sufficient lighting for about 200 sq. ft. of floor space; in a long laying house the lamps are spaced about 10 ft. apart. The lamps are located about 6 ft. above the floor.

Various times of turning the lights on and off have been used by flock owners as follows:

1. *Morning Lights.* Lights turned on at such time in the morning, according to the time of year, as to give a 13-hr. day up to dusk.

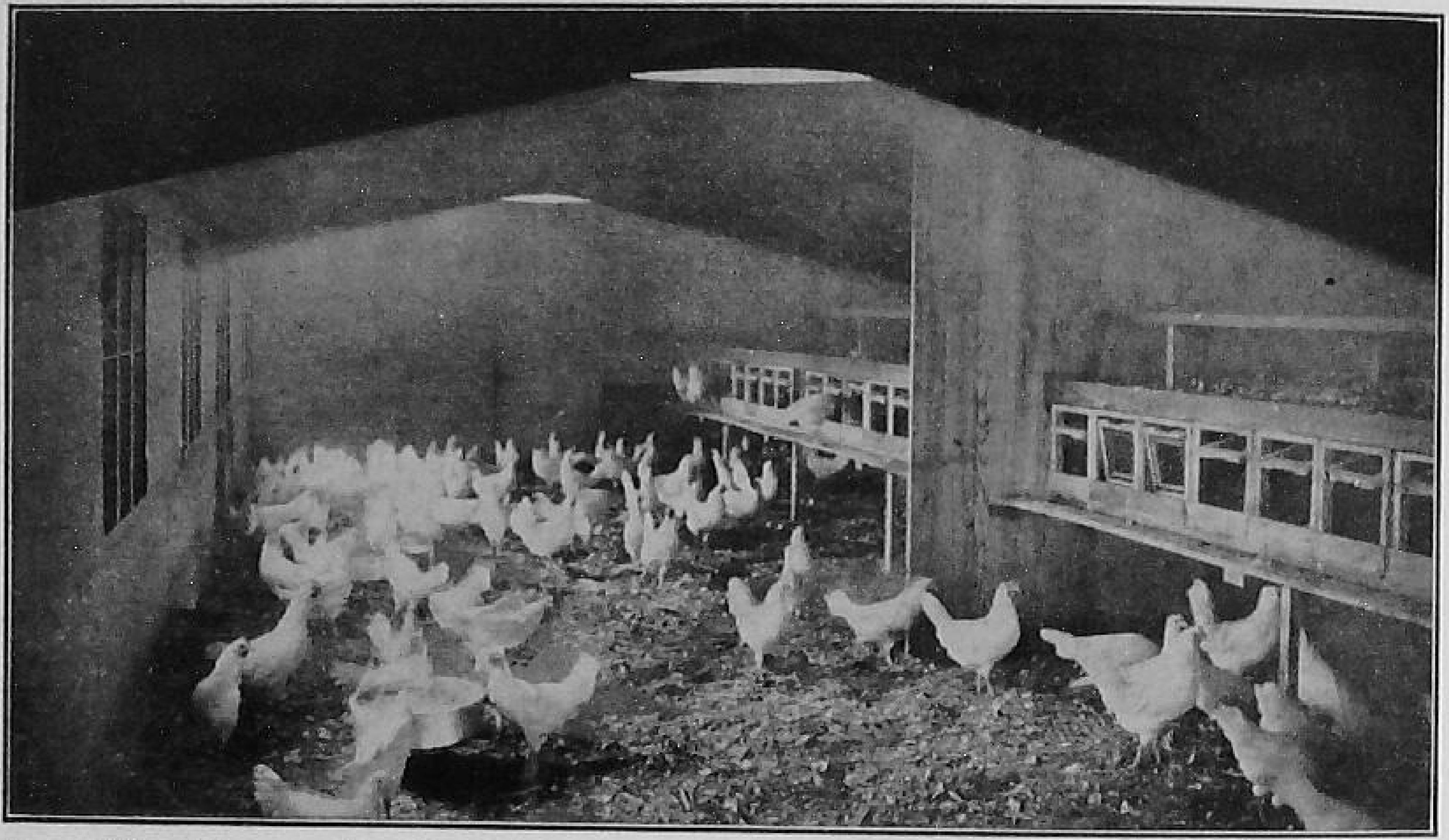


FIG. 171. The use of artificial lights in stimulating fall and winter egg production is of particular value in northern sections of the country.

2. *Morning and Evening Lights.* Lights turned on at 5 A.M. and off at daylight and then on again at dusk and off at 6 P.M. After the evening lighting, dimmers of low wattage must be turned on at 6 P.M. to permit the birds to go to roost.

3. *Evening Lights.* Lights turned on at dusk and off about 8 P.M., according to the time of year, to give a 13-hr. day. Dimmers are required.

4. *All-night Lights.* Electric lights of relatively low wattage left on all night usually makes this system more expensive than others. However, if gas at very cheap rates is available, this system of all-night lighting is practicable.

The lighting system most widely employed consists of using morning lights only, because it is simpler and at dusk the day's work is done. The flock owner can attend to anything in the house in the evening as soon as the birds have gone to roost. Also, no dimming system is necessary. It is very important to give the birds practically the same amount of

artificial light and daylight from day to day. Failure to turn the lights on a few mornings may cause a drop in egg production.

Artificial Lighting for Pullets. When laying pullets are placed in the laying house in the fall of the year, they are still in a growing condition. Giving them a 13-hr. day by the use of artificial lights in the morning stimulates egg production. Feed consumption is increased, so that they keep on growing and laying well at the same time. Morning artificial

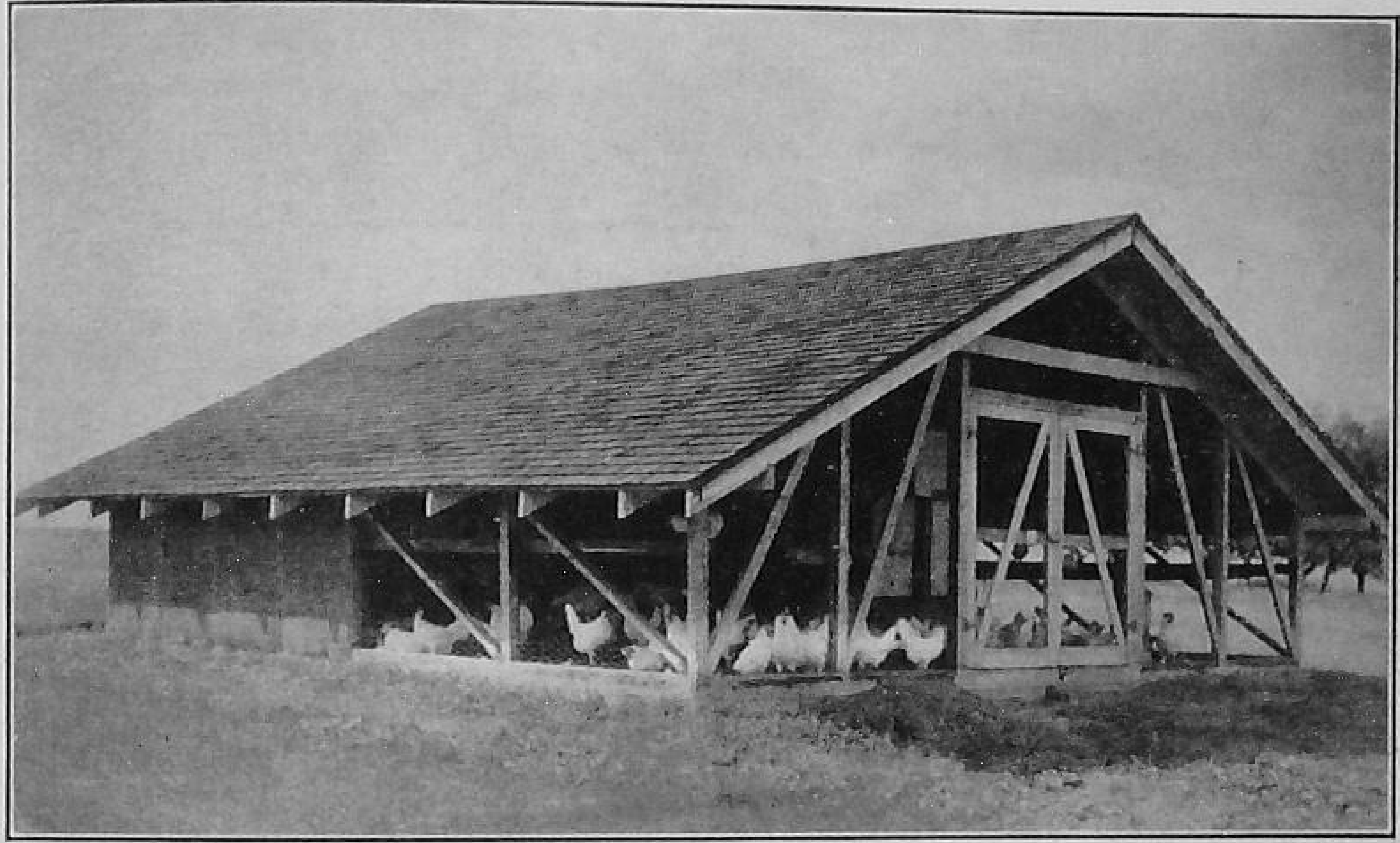


FIG. 172. Toward the close of the first laying year, about Aug. 1, the laying flock should be culled thoroughly, and in order to make room for the new crop of pullets, the unculled layers should be transferred to a well-ventilated shelter where they could be given artificial lighting until they have finished their first year of production. (*Pa. Agr. Ext. Service.*)

lighting should be continued until about Apr. 1. Feed and water should be available for the birds when the lights are automatically turned on early in the morning. In cold climates the water should be kept from freezing by the use of water heaters.

Artificial Lighting for Yearlings. During July and August egg production is likely to drop considerably. Some hens start to molt, and others also tend to lose in body weight and stop laying. Beginning about July 1, it is a good practice to cull the flock thoroughly. Care must be taken to prevent the birds from slackening in their feed consumption and thus losing body weight. By using artificial lighting, combined with a good feeding program, the yearlings can be kept in good laying condition until November.

Egg Production and Feed Consumed. The amount of feed consumed per dozen eggs produced is determined largely by the inherent laying capacity of the flock. Birds that have not been bred for high egg pro-

duction utilize most of their feed for maintenance and relatively little for egg production. On the other hand, birds that have been bred for high egg production utilize their feed much more efficiently in producing eggs than poorly bred birds. At the same time, unless bred-to-lay birds are well fed, they cannot produce eggs efficiently.

The amount of feed consumed by layers is influenced by their body size and the number of eggs produced. This is borne out by the data in Table 43.

Table 43. Average Amount of Feed Consumed per Bird per Year According to Average Live Weight and Number of Eggs Laid during the Year (National Research Council, 1944)

Average live weight, lb.	No. of eggs laid per year			
	0	100	200	300
	Average amount of feed consumed per bird per year, lb.[a]			
3.0	47	61	75	89
3.5	52	67	81	95
4.0	57	71	85	99
4.5	61	75	89	104
5.0	65	80	94	108
5.5	70	84	98	112
6.0	74	88	102	116
6.5	78	92	106	120
7.0	81	96	110	124

[a] For maintenance and the production of the indicated number of eggs per year.

From the time the pullets are placed in the laying house, they require more feed daily until they are about 10 months old, because pullets continue to grow until that time. As the rate of egg production increases during the fall and winter months, the amount of feed required increases. Birds that are confined to the laying house consume more mash and scratch than birds that have access to succulent pasture. Flocks that are culled regularly to maintain efficiency of production and flocks that suffer mortality require less feed as culling and mortality increase. Because of all these factors, it is easy to see why it is impossible to state exactly how much feed should be given a flock daily.

On the other hand, every flock owner should know the approximate amount of feed required by his or her flock. Table 44 gives the approximate amounts of feed required daily by 100 birds according to the body

weight of the birds and per cent daily production or the number of eggs laid daily per 100 birds.

Table 44 is intended to serve merely as a guide to flock owners in suggesting the approximate amounts of feed required daily per 100 layers.

The relation between the number of pounds of feed consumed per dozen eggs laid and the number of eggs produced in a year by White Leghorn pullets is shown in Fig. 173.

TABLE 44. APPROXIMATE AMOUNT OF FEED REQUIRED DAILY PER 100 BIRDS ACCORDING TO SIZE OF BIRD AND NUMBER OF EGGS LAID PER DAY PER 100 BIRDS
(T. C. Byerly, University of Maryland, 1941)

Per cent production	Body weight, lb.				
	3	4	5	6	7
	Feed required per 100 birds per day, lb.				
0	12.8	15.5	17.9	20.2	22.3
10	14.2	16.9	19.3	21.6	23.7
20	15.6	18.3	20.7	23.0	25.1
30	17.1	19.8	22.2	24.5	26.6
40	18.5	21.2	23.6	25.9	28.0
50	19.9	22.6	25.0	27.3	29.4
60	21.3	24.0	26.4	28.7	30.8
70	22.7	25.4	27.8	30.1	32.2
80	24.2	26.9	29.3	31.6	33.7
90	25.6	28.3	30.7	33.0	35.1
100	27.0	29.7	32.1	34.4	36.5

The curves in Fig. 173 show that White Leghorn pullets of the same size laying 100 eggs per year consume between about 7.7 and 8.7 lb. of feed per dozen eggs, whereas White Leghorn pullets laying 200 eggs per year consume between about 4.4 to 4.9 lb. of feed per dozen eggs.

Large-sized laying pullets require relatively more feed for maintenance than small-sized laying pullets and thus at the same level of egg production, large-sized laying pullets consume relatively more feed per dozen eggs produced. This is borne out by the data in Table 45.

The data in Table 45 were compiled without taking into consideration changes in the body weights of the birds in a flock. Naturally, when body weight is increasing in a bird that is laying, as in the case of laying pullets in the late fall and early winter, more feed is required than when body weight is not increasing in a bird that is laying.

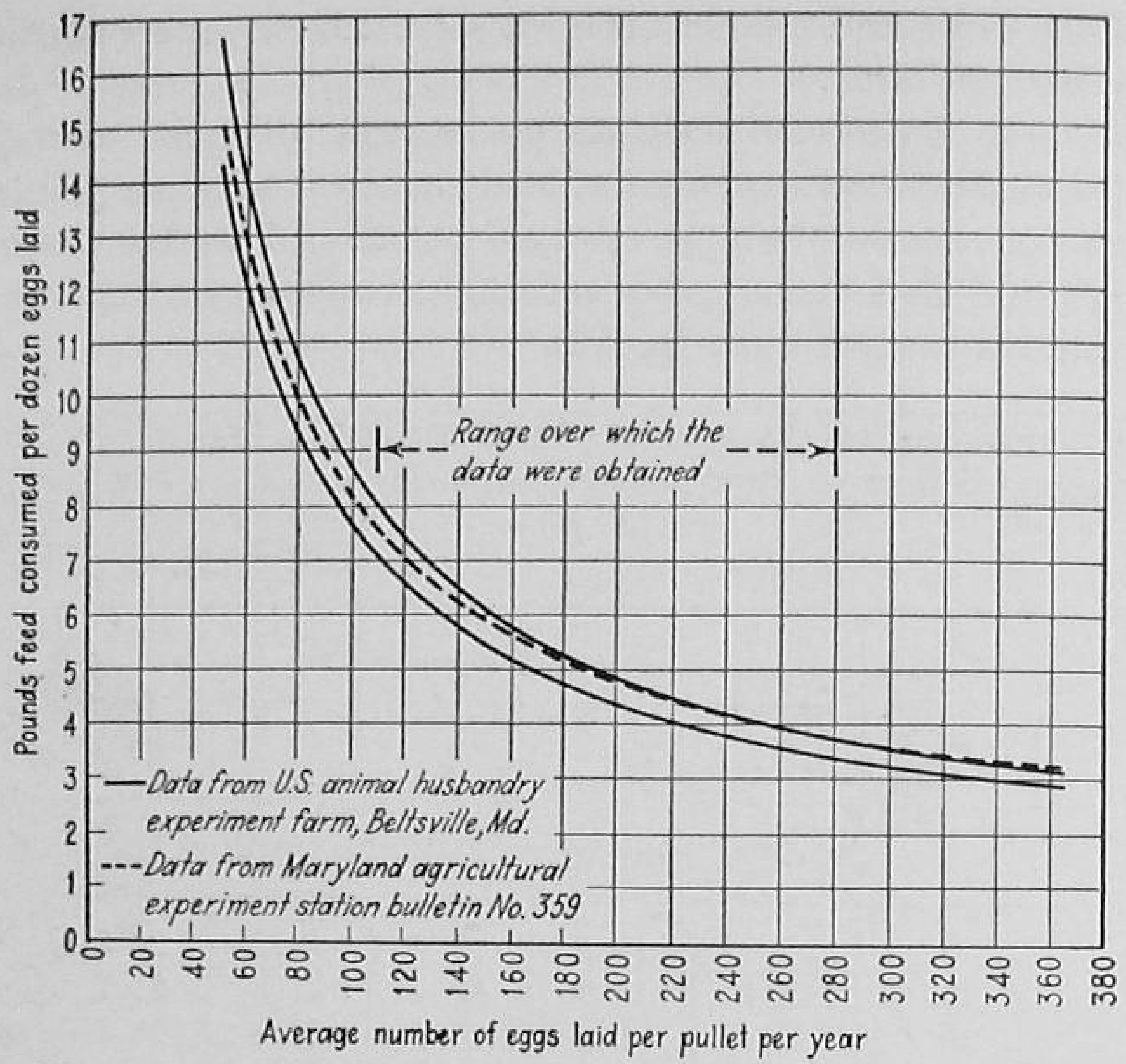


FIG. 173. The more eggs a pullet produces in a year, the less feed is required per dozen eggs. A White Leghorn pullet laying 100 eggs a year consumes almost twice as much feed per dozen eggs as a pullet laying 200 eggs a year. (*H. W. Titus*, 1940.)

TABLE 45. APPROXIMATE AMOUNT OF FEED REQUIRED PER DOZEN EGGS PRODUCED ACCORDING TO SIZE OF BIRD AND NUMBER OF EGGS LAID PER 100 BIRDS PER DAY
(T. C. Byerly, University of Maryland, 1941)

Per cent production	Body weight, lb.				
	3	4	5	6	7
	Feed required to produce 1 doz. eggs, lb.				
10	17.0	20.3	23.2	25.9	28.4
20	9.4	11.0	12.4	13.8	15.1
30	6.8	7.9	8.9	9.8	10.6
40	5.6	6.4	7.1	7.8	8.4
50	4.8	5.4	6.0	6.6	7.1
60	4.3	4.8	5.3	5.7	6.2
70	3.9	4.4	4.8	5.2	5.5
80	3.6	4.0	4.4	4.7	5.1
90	3.4	3.8	4.1	4.4	4.7
100	3.2	3.6	3.9	4.1	4.4

The data in Table 45 should be of very great interest to all flock owners. (1) It is shown that 100 birds laying 20 eggs per day require more than twice as many pounds of feed per dozen eggs produced than 100 birds laying 60 eggs per day. It is quite apparent, therefore, that high egg production increases the gross income obtained from the flock and the net income per dozen eggs produced. (2) The data in Table 45 indicate clearly that an increase in the price of feed increases the feed cost of

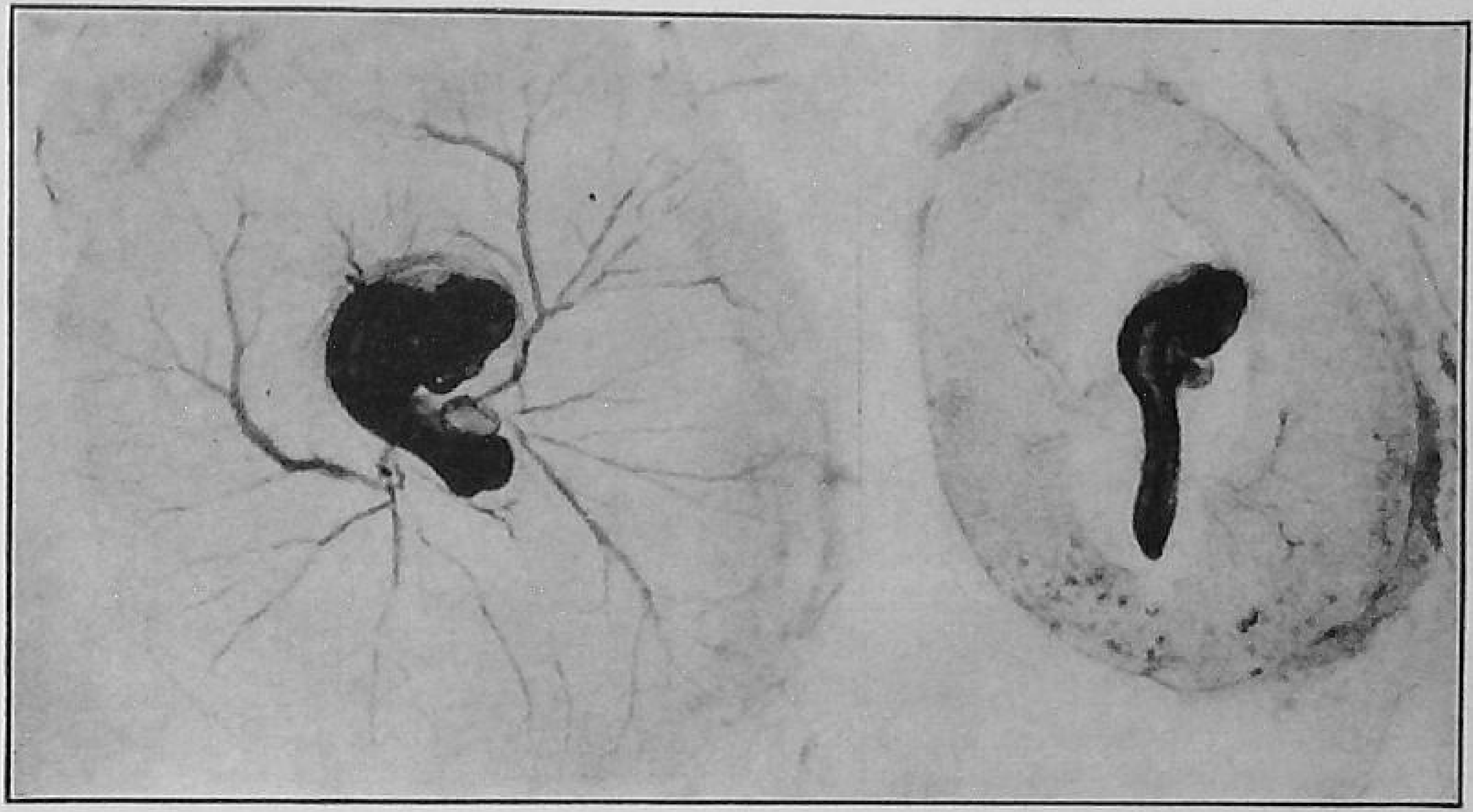


FIG. 174. Left, normal embryo of 84-hr. incubation. Right, an embryo of the same age in an egg produced by a hen fed a diet deficient in riboflavin. The blood system is disorganized, and the embryo shows the effects of retarded growth. (*A. L. Romanoff and J. C. Bauernfeind*, 1942.)

producing eggs relatively more among poor laying flocks than among good laying flocks. (3) It is evident from the data in Table 45 that an increase in the price of feed is relatively more costly with large-sized birds than with small-sized birds.

FEEDING BREEDING STOCK

Many of the laying flocks in the country are used for producing hatching eggs during the normal hatching season. In addition, some of these are also used for out-of-season hatching-egg production, largely to supply chicks for broiler producers. In all cases, high hatchability is very important from the economic standpoint. Also, usually the higher the hatchability the better is the quality of chicks hatched.

It is well recognized that birds given access to the ultraviolet rays of sunshine and to succulent green pasture usually produce eggs superior in hatchability to eggs produced by birds of the same strain kept in strict confinement. It is possible, however, to secure very good hatchability

from eggs laid by confined birds by adopting proper feeding methods. The recommended nutrient allowances given in Table 39 show that breeders need relatively more riboflavin, pantothenic acid, biotin. and manganese than layers kept solely for market-egg production.

Fig. 175. (*A*) Out of 100 eggs produced by hens receiving inadequately supplemented vegetable protein at a high level, 34 eggs failed to hatch and 19 of the chicks that hatched died during the first week. (*B*) Out of 100 eggs produced by hens fed a similar diet supplemented with fish meal, 15 eggs failed to hatch and 4 of the chicks that hatched died during the first week. (*H. R. Bird*, 1949.)

Vitamins A and D_3 are very important for good hatchability, the recommended nutrient allowances being the same as for market-egg production. With breeding stock kept in confinement, adequate vitamin-D supplements are especially important.

A marked deficiency of calcium results in decreased hatchability but is usually not a serious problem. Particular attention must be given to manganese in the case of layers being used for the production of hatching eggs.

As far as the effects of protein supplements on hatchability are concerned, milk products and good-quality fish meals usually give better results than most plant-protein supplements. This is probably due in part to minerals and to certain vitamins, some of which are still unidentified, contained in animal-protein supplements. Cottonseed meal and soybean meal have been shown to lower hatchability, but if the proper levels of animal-protein supplements are used in addition to soybean meal, satisfactory hatchability can be secured.

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CHAPTER 11

DISEASE PREVENTION AND CONTROL

The high mortality that occurs annually in the chick and adult flocks of the country is one of the outstanding drawbacks of the entire poultry industry. Not only is the economic loss from dead chicks and hens very great, but in addition there should also be counted the cost of retarded growth, poorly finished market birds, and decreased egg production among the birds that manage to live but are infested with parasites and infected with disease organisms.

Disease is disseminated by means of contact between infected and healthy birds and by the contact of healthy birds with contaminated soil and water. Birds that have recovered from an infection may become carriers of disease-inducing organisms. Flock attendants frequently carry the organisms on their hands, shoes, clothing, and utensils from bird to bird in a flock and from flock to flock. Contaminated feed spreads disease. The hatching in the same incubator of eggs from many different flocks, securing baby chicks from several different sources, and shipping birds from laying contests and poultry shows to widely scattered places are important factors in the dissemination of various diseases. Pigeons, sparrows, and other wild birds often play the role of disease disseminators by carrying the organisms on their feet to distant communities. Flies, fleas, and other insects frequently serve as disseminators of disease without themselves being infected.

When a Disease Outbreak Occurs. Since losses from mortality are often so costly, especially in the case of partially grown and adult birds, it is very important that every flock owner be on the alert at all times to detect the slightest indication of any disease condition assuming epidemic proportions. In many flocks there are nearly always a few chickens that appear unthrifty or definitely sick. Unless they are culled from the flock promptly, they may cause an epidemic that will result in heavy mortality.

It is very difficult for most flock owners to diagnose the cause of a disease outbreak in many cases. As a matter of fact, much of the mortality that occurs is due to pathological conditions wholly unrelated to specific disease manifestations. An examination of the internal organs does not always make it possible to determine the specific cause of death.

In cases of a serious outbreak of disease, a thorough diagnosis is very important and should be done by a veterinarian, a pathologist, or a bacteriologist. In most cases the diagnosis should be conducted in a properly equipped laboratory where microscopes and other apparatus make it possible to examine various tissues in detail.

Live sick chickens should be taken or shipped to the laboratory for examination. Dead specimens may also be taken, but only birds which have died quite recently. Dead birds should be cooled thoroughly before being packed for shipment. There is little use in having a diagnosis made, however, unless complete information is given concerning the nature of the disease outbreak, the number of birds affected, the breeding, feeding, and management of the flock. The more fully the flock owner cooperates with the person conducting the post-mortem examination, the greater are the chances of the investigator determining the cause of the disease outbreak. Once the cause has been determined, proper control measures can be taken to reduce further losses.

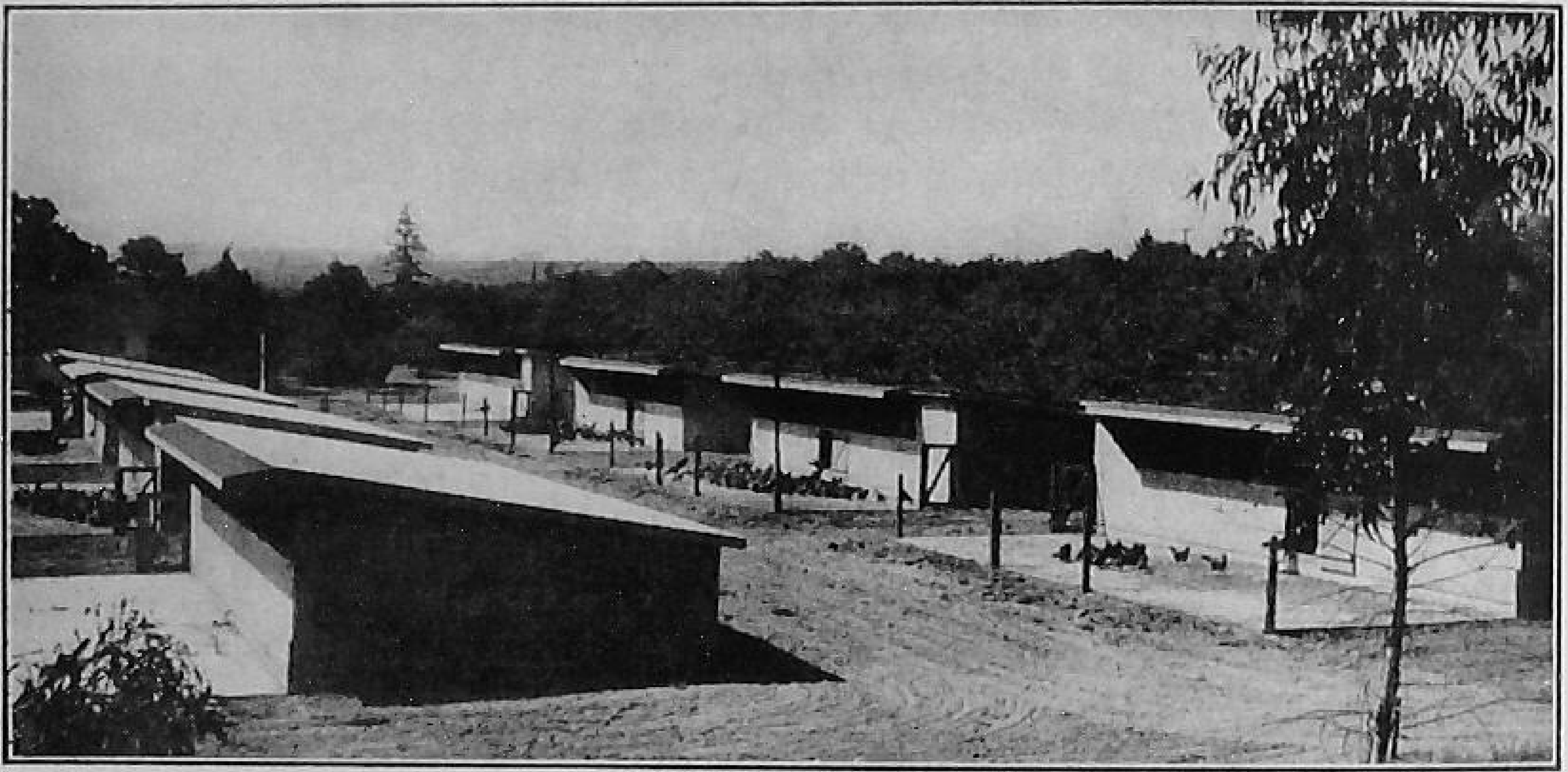

FIG. 176. Concrete yards in front of laying houses on farm of Valentine Brothers in California as a means of preventing the spread of disease. (*W. E. Clark, New Hampshire Breeder.*)

EXTERNAL PARASITES

External parasites that infest chickens include lice, mites, ticks, fleas, and sometimes bedbugs. They multiply rapidly and if not kept in reasonable control may seriously reduce returns from the flock.

Lice. There are about 40 different species of lice, the most important from the poultryman's standpoint being the body louse, the head louse, and the shaft louse. Lice complete their life cycle on the body of the

host and can only live for about 5 days away from the body. The entire life cycle takes only about 2 or 3 weeks to complete, and one pair of lice may produce as many as 120,000 progeny in a few months. Growing chickens heavily infested with lice appear unthrifty.

Dusting. Powdered commercial sodium fluoride is commonly used, 1 lb. being sufficient for treating about 100 birds. Sodium fluoride is poisonous to humans and other animals if taken internally. Every bird in the flock must be treated by holding it at the base of the wings and rubbing a pinch of the powder thoroughly among the feathers on the head, neck, breast, each thigh, on the underside of each wing, at the base of the tail, below the vent, and two pinches on the back. A powder shaker may be used for dusting birds with sodium fluoride, in which case it may be diluted with three times its bulk of flour or fine dust. A dusting powder containing from 5 to 10 per cent DDT, (poisonous to humans), is apparently as effective as sodium fluoride if all the birds in the flock are treated.

Dipping. A flock infested with lice may be treated faster by dipping each bird in a solution containing 1 oz. of sodium fluoride or sodium fluosilicate per gallon of warm water. Adding 1 oz. of near-neutral soap per gallon increases the efficiency of the dip. Dipping should be done only on a warm day, warm enough to allow the birds' feathers to become thoroughly dry. Each bird, held by the base of the wings, is plunged into the dip, and the other hand is used to ruffle the feathers to allow the dip to penetrate to the skin. Then the head is ducked twice, and the bird is withdrawn and held for a few seconds to allow draining before being released.

Fumigation. A relatively simple method of controlling lice is by fumigation, painting the roosts with a nicotine sulfate 40 per cent solution (Black Leaf "40"). Eight ounces per 100 ft. of roost is painted on the top on still nights when the temperature is about 60°F., some ventilation in the house being necessary. Since the eggs of body and shaft lice are not destroyed by this method, a second painting is necessary in about 10 days. This method does not control head lice. Nicotine sulfate is extremely poisonous to humans if taken internally.

Apparently, one of the simplest and most effective methods of ridding birds and houses of lice is to fumigate with hexachlorocyclohexane (hexa-chloro-cyclo-hexane), designated briefly as "HCCH." This is an innocuous fumigant that kills body and fluff lice and apparently their eggs. Either of the following preparations may be used: (1) a solution containing 10 per cent HCCH and 90 per cent benzol; (2) a suspension containing 25 per cent wettable HCCH powders and 75 per cent water. Application to roosts and interior of the house may be made with a

brush or sprayer, preferably on warm days. One properly made application should be effective for several months.

Red Mites or Roost Mites. These and other mites which infest poultry are barely visible to the unaided eye and in numerous cases multiply so rapidly as to cause considerable damage before their presence is discovered. The life cycle of mites consists of the egg, the larva, the nymph, and the adult stages, the life cycle being completed in from 1 to 4 weeks.

Red mites are bloodsucking parasites that feed on the birds at night and hide in cracks and crevices during the day. Adult mites may live for several months without food. Strong insecticides are necessary for their control. The flock owner should be on the lookout for any indication of red-mite infestation, such as unthriftiness among the birds or small eight-legged red (blood-filled) insects around the roosting quarters or on the birds at night.

In cases of infestation, the poultry house should be cleaned and thoroughly disinfected, especially the roosts and roosting quarters. The nests should be flushed with scalding water. Effective sprays for killing red mites include: Anthracine-oil wood preservative (carbolineum) diluted with an equal quantity of kerosene; a coal-tar cresol disinfectant in 10 per cent dilution with water; equal parts of kerosene and used crankcase oil. It is very necessary to see that the spray is forced into all cracks and crevices. Two treatments at about 10-day intervals are sometimes necessary to destroy red mites. The birds should be kept out of the house until the spray has soaked thoroughly into the wood.

Northern Fowl or Feather Mites. Although resembling the red or roost mite, the northern fowl mite occurs on birds and their surroundings more or less continuously. Feather mites are vicious bloodsuckers and may even cause scabs in the skin. When a badly infested bird is handled, the feather mites crawl over the hands and arms. If many birds in the flock of chickens with white plumage appear to have dirty plumage, the flock owner should be suspicious of a heavy infestation of northern fowl or feather mites. Extremely fine sulfur should be applied as a powder, rubbing generous amounts thoroughly over various parts of the body, especially around the vent, under the wings, and on the head, neck, back, and thighs. This dusting should be repeated in 10 days. The nests should be cleaned out thoroughly and then dusted. The roosts should be treated with a 40 per cent solution of nicotine sulfate, repeating the treatment at 3-day intervals at least three times.

Scaly-leg Mites. As the name indicates, these mites produce lesions under the scales of the shanks and less frequently on the skin of the comb and wattles, scales and crusts being formed. If the infestation of the

shanks is severe, the birds may be crippled. The life cycle of the mite is completed on the shank or skin, and uninfested birds may become infested as the result of contact with infested birds or with their surroundings. When scaly-leg mites are discovered in a flock, the house should be cleaned frequently, especially the roosts and roosting quarters, which should be sprayed thoroughly in the same manner as recommended for controlling red mites. Also, the shanks of each infested bird should be dipped in a mixture of 1 part kerosene and 2 parts raw linseed oil,

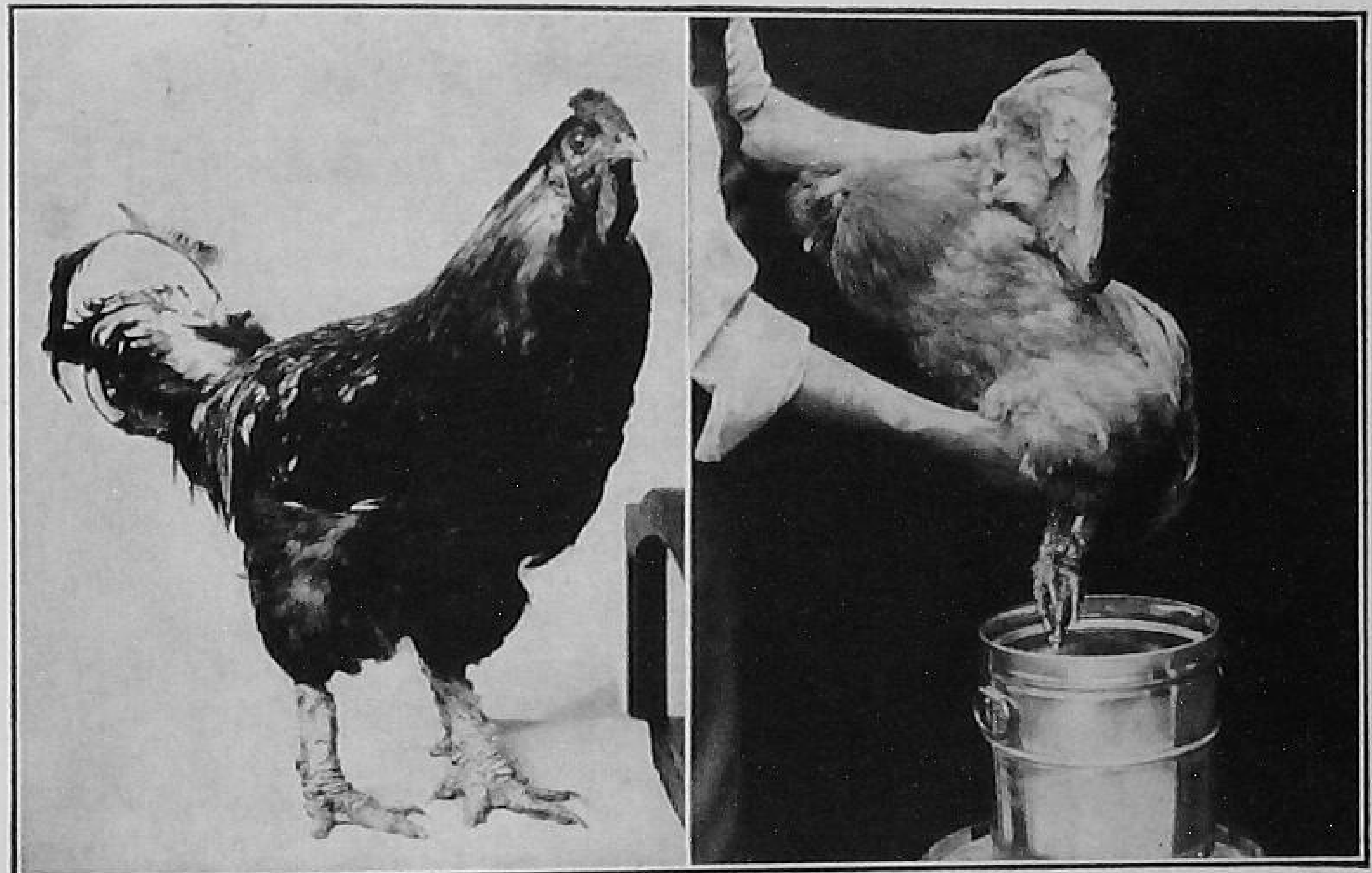

FIG. 177. Left, chicken affected with scaly-leg mite. (*U.S. Dept. Agr.*) Right, dipping the legs of a chicken in petroleum to control scaly-leg mites. (*F. C. Bishopp, Bureau Entomology and Plant Quarantine, U.S. Dept. Agr.*)

taking care not to get the mixture on the skin. When the comb and wattles are affected, phenol ointment, 2 per cent strength, or sulfur ointment, 15 to 20 per cent, may be applied to these parts as well as to the shanks.

Bedbugs. Bedbugs usually feed at night, so that control measures must be directed against them during the daytime. In order to get rid of bedbugs, the birds should be removed in the daytime and then the uncleaned house or infested batteries should be sprayed thoroughly with 5 per cent DDT in refined kerosene, after which the house or batteries should be cleaned and sprayed again before the birds are returned. All necessary precautions should be taken against fire breaking out. In place of kerosene, wettable-dust DDT powders could be used in making a finished spray containing 5 per cent DDT.

Fowl Ticks. These external parasites are bloodsuckers larger than mites and are more common in the southern part of the United States than in northern parts. Effective control measures are similar to those for controlling red mites. It is necessary to treat trees or other objects near the house. All trash should be burned. In cases of serious infestations, several treatments may be necessary.

INTERNAL PARASITES

Chickens on range are always seeking food in the superficial layers of the soil, which is often thoroughly contaminated with living organisms of all kinds, including various insects or earthworms that serve as hosts for the completion of the life cycle of internal parasites that infest poultry. Land that is bare, rarely cultivated, and over which chickens range year after year is a particularly favorable breeding ground for many of the internal parasites and their intermediate hosts.

Small Roundworms. Because many small roundworms are long and slender, they are often called "threadworms," and because they usually invade the chicken's crop, they are sometimes called "crop worms." Among birds severely infested, the face becomes pale, growth is retarded, and feathers are ruffled. Treatment is only partially effective, apparently the best method being to administer carbon tetrachloride or tetrachlorethene in 1 cc. doses. Raising chickens on clean range well covered with grasses and legumes and frequent moving of the range shelters, feed hoppers, and water containers are the best precautions against damaging infestation of small roundworms.

Large Roundworms. The large roundworm, *Ascaridia galli*, is one of the most common intestinal parasites of poultry, often causing serious damage among growing chickens under 4 months of age. The parasite usually establishes itself in the small intestine of the chicken. Large roundworms vary in length from about 1.5 to over 4 in., and in some cases they may practically fill the intestine.

If chickens are reared under the conditions suggested for controlling small roundworms, there should be no serious trouble from large roundworms. In case neglect in providing sanitary range has resulted in serious infestation, the following treatment may be given: 4 cc. of carbon tetrachloride per 2.2 lb. of body weight. Where sanitary rearing conditions are not provided, it may be advisable to feed the following mixture as a preventive measure: 15 g. of nicotine sulfate (Black Leaf "40"), 151 g. of phenothiazine, 287 g. of bentonite (a claylike material) per 44 lb. of the regular mash. This medicated mash should be fed for 3 consecutive days at intervals of 3 weeks. Feeding a mash containing 0.04 per cent of thyroactive iodocasein has been shown to enable parasitized chickens

to maintain normal growth. Phenothiazine and nicotine in proper proportions in the mash are effective in controlling large roundworms.

Caecal Worms. The caecal worm, *Heterakis gallinae*, establishes itself in the caecum of the chicken. Although the caecal worm may cause considerable damage to chickens, it is very important to remember that it is probably a carrier of the blackhead organism that causes such heavy losses among turkeys. For this reason, turkeys should not be allowed to mingle with chickens.

Either one of the following treatments may be given in case of serious caecal-worm infestation: (1) a mixture of 0.1 cc. of oil of chenopodium in 5 cc. of olive oil is injected into the rectum of birds weighing 1.5 lb.,

FIG. 178. A slit in the intestines reveals a chicken heavily infested with roundworms. (*G. C. Holm, C. E. Lampman, P. Moore, and W. B. Ardrey, University of Idaho.*)

using a hard rubber syringe and doubling the amount of each ingredient for birds weighing 3 lb. or more; (2) administering capsules containing 0.5 g. of phenothiazine, repeated doses being given if necessary. Phenothiazine may be fed at the rate of 1 lb. per 100 lb. of mash. The treatment recommended for large roundworms is effective for caecal worms.

Gapeworms. These parasites are roundworms that inhabit the trachea of young chickens, and if the infestation is severe, a disease known as "gapes" is produced. Gapeworms are also called "red-worms" because of the red color of the female, and "forked-worms" because the male, much smaller in size than the female, is attached to the female at her anterior end in such a way that the two sexes have the form like the letter Y.

Young birds heavily infested with gapeworms have difficulty in breathing and continually throw their heads upward and forward in order to draw in air. Feed consumption is restricted, growth is retarded, and

the mucous membrane of the trachea becomes inflamed. Since adult turkeys, when allowed to mingle with very young chickens, serve as carriers of gapeworms in transmitting gapeworm disease to chickens, growing chickens should never be allowed to mingle with adult turkeys, although the latter apparently suffer but little from gapeworm infestation.

For treatment, the infested birds are placed in a tight box into which barium antimonyl tartrate is blown by means of a dust gun. One ounce of the powder is sufficient for a box with a capacity of 8 cu.ft. The powder remains suspended in the air in the box for a long time and upon

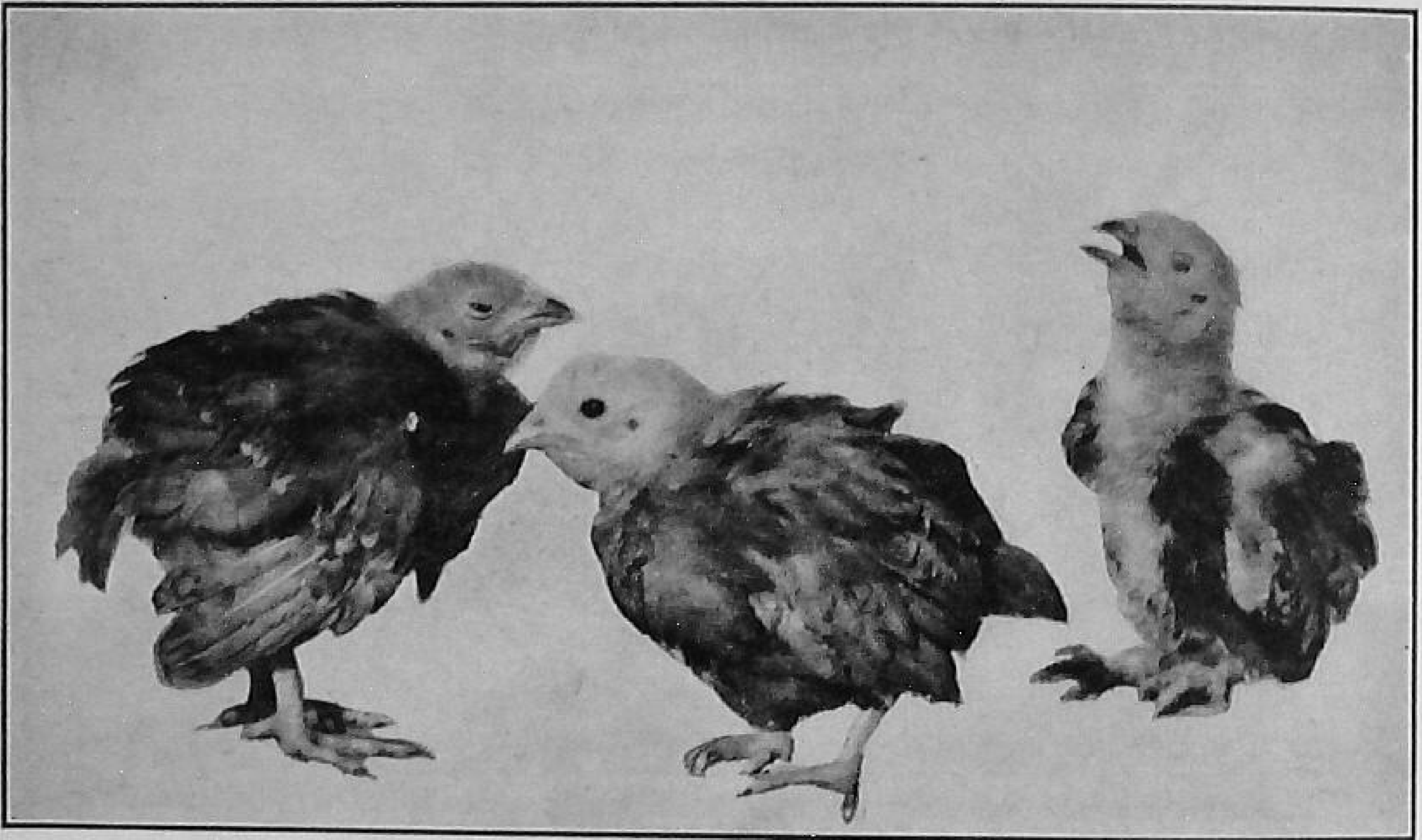

Fig. 179. Chickens suffering from gapeworms. (*Bur. Anim. Indus., U.S. Dept. Agr.*)

being inhaled by the chickens serves as a contact poison for the gapeworms. One-third of an ounce is blown into the box at intervals of about 5 min., the box being tilted occasionally to keep the powder suspended. About 5 to 10 min. after the third treatment, the birds are released.

Tapeworms. There are several species of tapeworms that infest the small intestines of chickens, an intermediate host being necessary for the completion of their life cycle. Structurally, tapeworms are flat and consist of a head or scolex having suckers for attachment to the lining of the intestinal tract, a neck in some species, and the main portion of the body consisting of segments or proglottids, which collectively are known as the "strobila." Tapeworms obtain their food by absorption through the surface of their bodies. They grow from their necks posteriorly, the posterior segments being sloughed off at intervals. Some tapeworms attain a length of 10 in. The intermediate hosts necessary for the com-

pletion of the life cycle of tapeworms include ants, flies, slugs, earthworms, and ground beetles.

Heavy tapeworm infestation often causes enteritis and diarrhea, retards growth in young chickens, and lowers egg production among layers. Paralysis of the limbs sometimes results from tapeworm infestation, and the birds appear unthrifty.

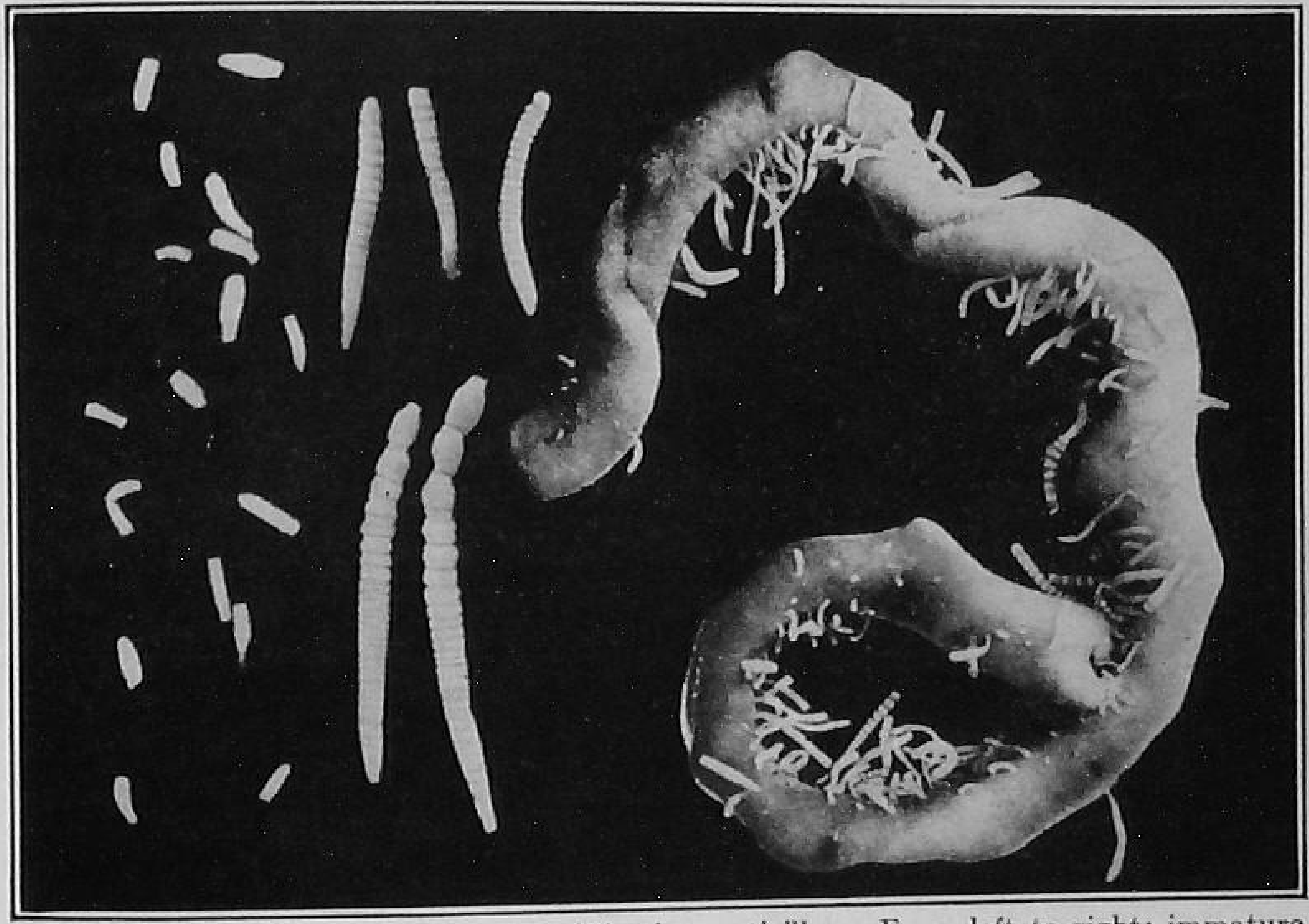

FIG. 180. A common tapeworm, *Raillientina cesticillus*. From left to right: immature stage, magnified 1½ times; mature stage magnified 2 times; intestine turned inside out showing tapeworms attached to wall of intestine. (*University of Illinois, Dept. Vet. Science.*)

Raising chickens on clean range and moving the range shelters, feed hoppers, and water containers will help to keep tapeworm infestation under control. In cases of heavy infestation, treatment is very difficult for the simple reason that, to date, no method of treatment has been found that will remove the head or scolex of the tapeworm. Removing the segments is of little avail because new ones are quickly regenerated. A reasonable degree of sanitation in rearing young chickens and in keeping laying flocks is the only recommendation that can be made with a view toward keeping tapeworm infestation at a minimum.

PROTOZOAN DISEASES

A protozoon (plural, protozoa) is the smallest kind of animal in existence and is a one-celled creature, some forms of which cause considerable

damage in the higher forms of animal life, including chickens. Although certain other protozoan diseases are important, by far the most outstanding one from the standpoint of economic importance is coccidiosis.

Coccidiosis. Heavy mortality sometimes results from coccidiosis, especially in young chickens up to 3 months of age. The disease is caused by coccidia, very small protozoan organisms which multiply very rapidly in the intestines of chickens. There are eight species, among the most important of which are *Eimeria tenella* and *Eimeria necatrix*. *E. tenella* invades the lining of the caeca and produces the caecal type of coccidiosis which is often referred to as "bloody coccidiosis." *E. necatrix* and the other species of coccidia produce the intestinal type of coccidiosis, which

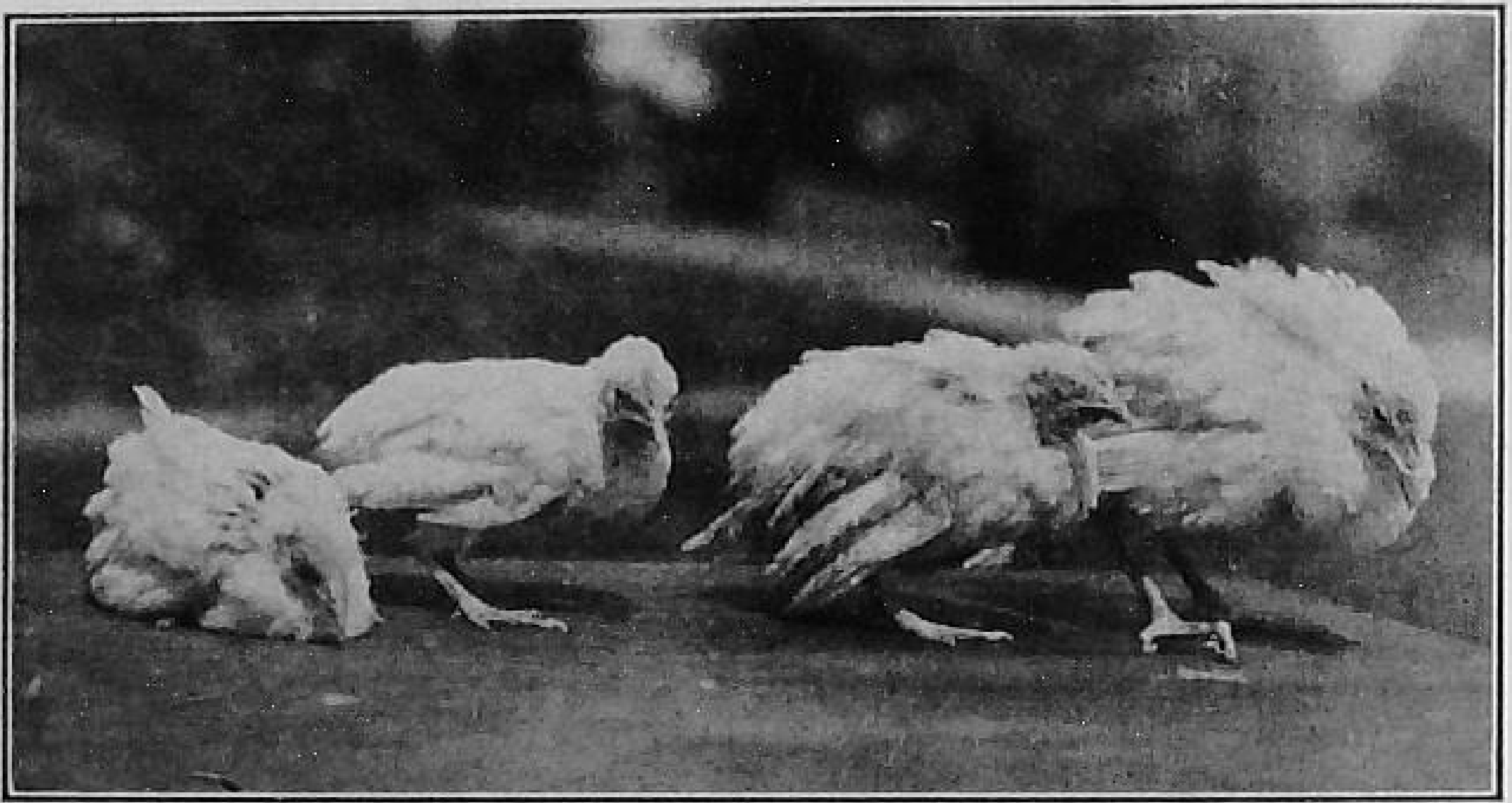

FIG. 181. Chicks infected with coccidiosis. (*Sawyer and Worley.*)

usually occurs at about 8 to 10 weeks of age. The intestinal type of coccidiosis may be either of the acute or chronic type, the former often causing death from 5 to 7 days after infection and the latter resulting in a lingering illness.

Chicks heavily infected with caecal or intestinal coccidiosis become droopy, look unthrifty, usually have ruffled feathers and pale beaks and shanks, and eventually become so emaciated that death follows. In addition, in the case of caecal coccidiosis, the droppings are streaked with blood. The mortality in a flock may be high and may occur very suddenly. Old birds that have become immune to the disease are a constant source of reinfection. No old birds should ever be allowed on the range with growing chickens.

Control. In order to control losses from coccidiosis, it is necessary to restrict the severity of the disease during the period of exposure in order to permit the birds to develop some degree of immunity. For this purpose, treatment with certain sulfa drugs or sulfonamides has been found to be quite effective because they restrict or completely arrest

the multiplication cycle of coccidia within the intestinal tract of the chicken. Therefore, when mash or water containing sulfa drugs is given at the correct time, the severity of the coccidial attack is limited and the birds are given a chance to overcome the disease and develop immunity against subsequent exposure. It should be kept in mind that sulfa drugs will not control coccidiosis unless the birds are exposed to infection during the period of treatment. Sulfa drugs are apparently of little value if the disease is well advanced. Since all the birds in almost any flock are probably not exposed to infection at the same time, the sulfa drugs must be given intermittently, although at least one of them may be

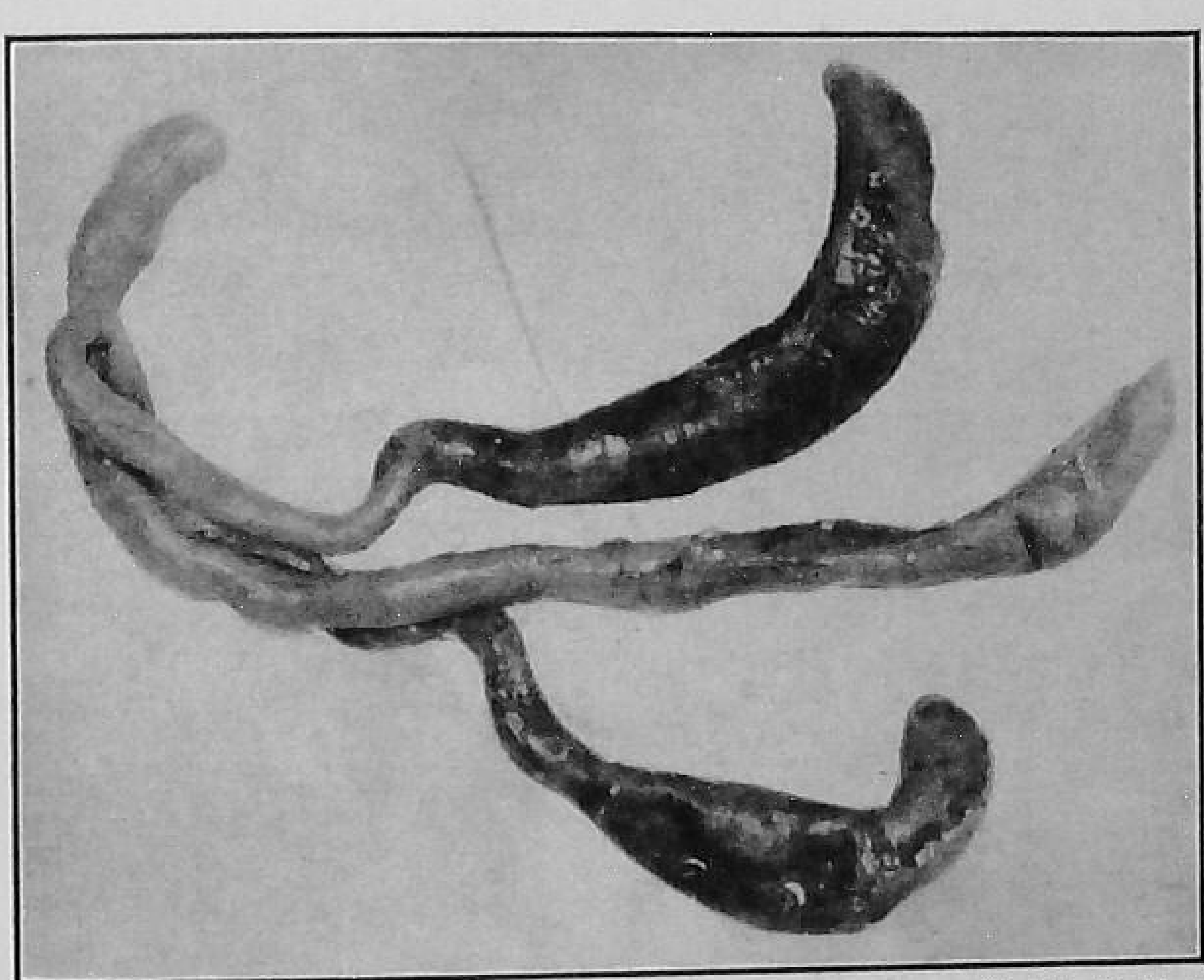

FIG. 182. Caeca filled with blood in acute coccidiosis. (*H. M. DeVolt.*)

given continuously at very low levels as a preventive measure. Several diphenols and biphenols apparently possess significant anticoccidial properties.

Poultrymen desiring to use sulfa drugs for controlling losses from coccidiosis should be guided by the instructions of manufacturers or should consult a pathologist or veterinarian.

Many poultrymen make a practice of starting chicks on litter that has been previously used either by growing chickens or laying hens. This practice enables the chicks to build up immunity to the disease at an early age. During the brooding period, the built-up litter system is employed.

Blackhead. The term "blackhead" is really a misnomer because a darkened head resulting from infection is not a characteristic of this

disease only. The proper name for this disease is "enterohepatitis" and is caused primarily by the organism *Histomonas meleagridis.* This causative organism is harbored by the common poultry caecum worm, *Heterakis gallinae.* Although the caecum worm is often found in chickens, they rarely suffer from blackhead infection but transmit the disease through their droppings to turkeys. Since the disease is much more serious in turkeys than in chickens, it is obvious that turkeys should be kept entirely separated from chickens of all ages. Also, turkeys should not be allowed on soil previously used by chickens.

BACTERIAL DISEASES

Bacteria of various kinds are always present in the intestinal tract of the chicken, some of them being quite harmless, although others give rise to specific bacterial infections that often cause high mortality.

Botulism. Also known as "limberneck," the cause of this disease is a highly poisonous substance produced by the microorganism *Clostridium botulinum.* This microorganism is apparently quite prevalent in the soil

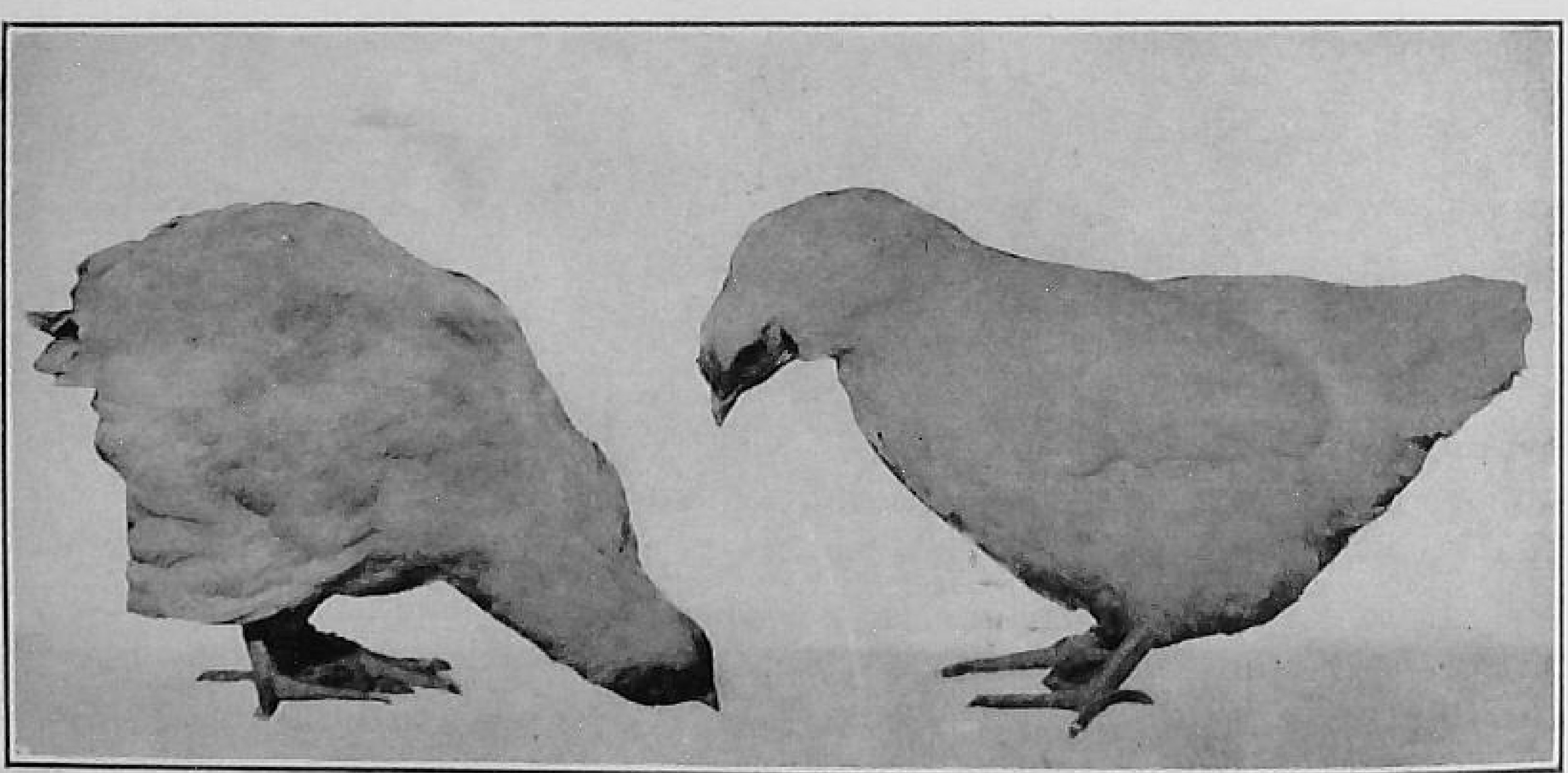

FIG. 183. Showing typical symptoms of botulism in chickens. (*A. J. Durant, Vet. Dept., Mo. Agr. Exp. Sta.*)

in all parts of the country, although botulism in chickens is usually due to their eating decomposed meat, spoiled grain or canned vegetables, or the flesh of birds that have died of the disease. Botulism causes paralysis, especially of the leg and wing muscles so that the birds are unable to walk and the wings rest on the ground. Where botulism occurs in any flock, careful examination should be made of the premises to see if dead animals or other possible sources of contamination exist.

Fowl Cholera. Fowl cholera is a highly infectious, rapidly fatal disease, caused by *Pasteurella avicida,* a microorganism that multiplies

to enormous numbers in the blood and various organs of the body, producing a septicemia, or blood poisoning. The disease is carried by sick or recently recovered birds, by wild birds, persons, other animals, or poultry utensils that have been on infected premises. Cholera spreads rapidly throughout the flock, because the first birds to become infected give off great numbers of the microorganisms in their droppings, and these microorganisms are picked up by the other birds. The disease is most common in wet or cold weather.

The first symptom is a yellowish coloration of the droppings, followed by yellowish, brownish, or greenish diarrhea. An infected bird becomes droopy, feverish, and sleepy and sits with the head drawn down or turned backward, rested in the feathers about the wing. The appetite diminishes, thirst increases, and breathing becomes difficult. Finally, the bird is unable to stand, lying with the beak resting on the ground. The comb and wattles often turn a dark bluish red.

During an acute outbreak sickness is seldom noticed more than 24 hr. before death, which usually occurs within 3 days from the time of infection. The disease may destroy the greater part of a flock in a week and then disappear, or it may linger in a chronic form for months, only occasionally killing a bird. In the chronic form a continually increasing weakness, loss of weight, paleness of head, and, finally, an exhausting diarrhea are outstanding characteristics. Sometimes the joints of the wings or legs swell, which may break and discharge a creamy or cheesy mass.

Preventive measures should be undertaken against the spread of infection. The first fowls showing acute symptoms should be destroyed and burned. The houses and yards should be thoroughly cleaned at frequent intervals and disinfected with a compound solution of cresol in 3 per cent solution or with a reliable coal-tar disinfectant in proper dilution. Drinking vessels and feed troughs should be disinfected daily.

Mortality from fowl cholera can be reduced greatly by giving a flock in which an outbreak has occured 0.1 per cent concentration of sodium sulfamethazine in the drinking water. Since birds that are not infected at the time of treatment remain susceptible and are liable to become infected if medication is discontinued, additional medication is necessary to check the outbreak. Sulfathiazole added to an all-mash diet at the level of 0.5 or 1.0 per cent is effective to a considerable degree in controlling fowl cholera. Sulfaquinoxaline is largely effective in preventing the spread of the respiratory form of fowl cholera within a flock fed continuously an all-mash diet containing 0.33 per cent (1 lb. per 3,000 lb. of mash) of the drug.

Fowl Tuberculosis. Avian tuberculosis is a chronic infectious disease of great importance not only as a disease of chickens but also because it

may be transmitted from chickens to swine. Avian tuberculosis is caused by *Mycobacterium avium*, which may be introduced into a flock by the purchase of infected birds or by wild birds and other animals. The disease is most prevalent in the North Central states.

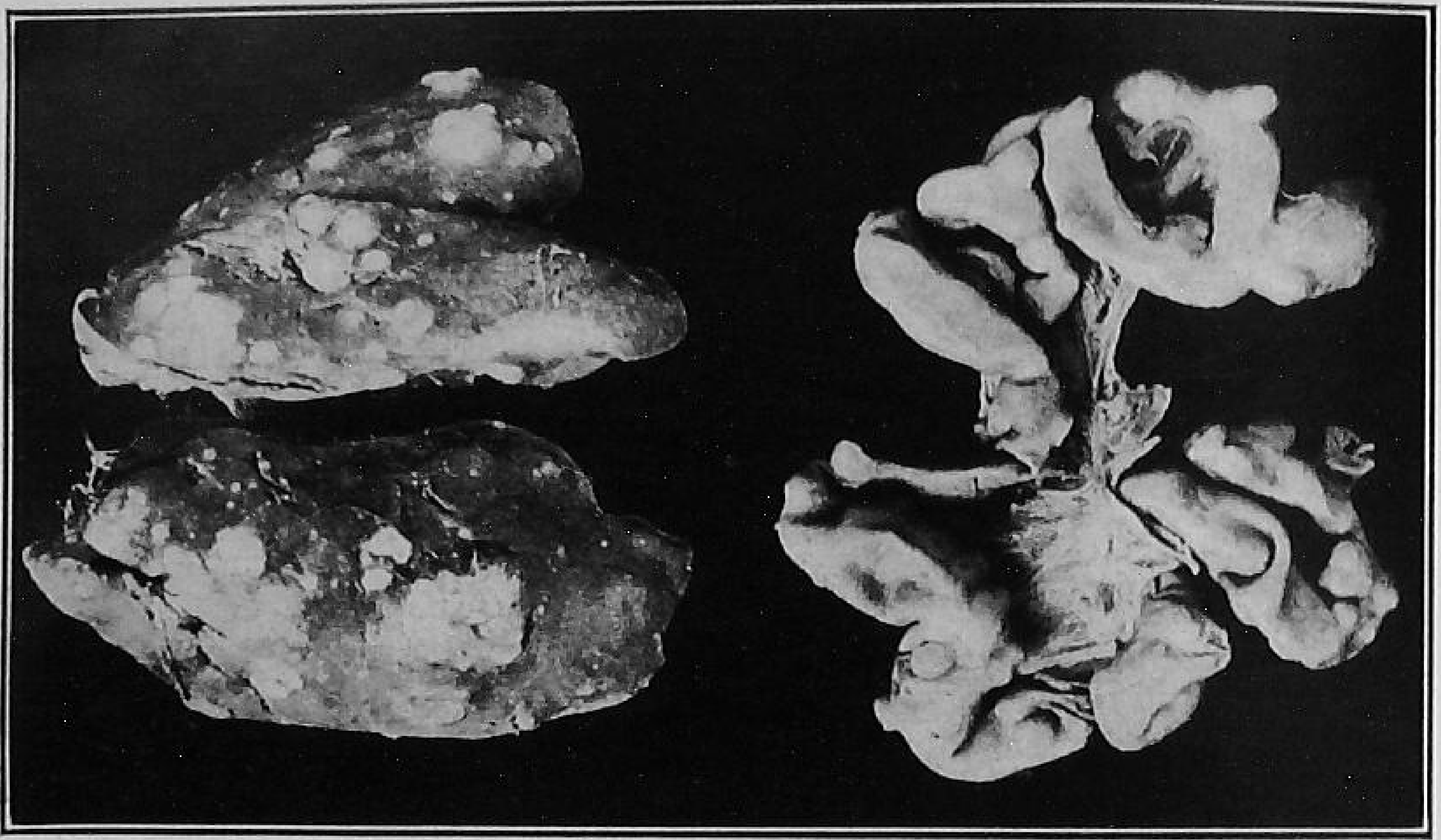

FIG. 184. Tuberculosis nodules on liver and intestines of a chicken. (*J. R. Beach, University of California Dept. Vet. Science.*)

The disease usually progresses slowly so that symptoms are, for the most part, observable only in birds over 1 year of age, as shown by the data in Table 46.

TABLE 46. EXTENT OF AVIAN TUBERCULOSIS INFECTION IN ALL-PULLET FLOCKS AND IN MIXED FLOCKS (HENS AND PULLETS) IN 10 COUNTIES IN IOWA, 1946, 1947, 1948
(C. D. Lee, Veterinary Division, Iowa State College)

Kind of flock	No. of flocks	No. of birds	No. of birds infected	Per cent of birds infected	No. of flocks infected	Per cent of flocks infected
All-pullet............	152	30,164	79	0.26	19	12.50
Mixed..............	226	51,268	2,940	5.73	143	63.27

In advanced stages of the disease there is loss in weight, dullness, dry appearance of the feathers, and diarrhea with greenish or yellowish droppings. On post-mortem examination the liver, spleen, and intestines are covered with yellowish-colored tubercles of varying sizes.

In living fowls, tuberculosis may be diagnosed by applying the tuber-

culin test, as in the case of dairy cattle. The test should be performed by a pathologist or veterinarian.

In many respects, the simplest method of controlling losses from fowl tuberculosis is to sell all birds at the end of their first laying year and practice strict sanitation, taking particular precautions to provide non-infected housing quarters and range for the growing stock and the laying flock.

Fowl Typhoid. This disease is an acute infectious disease of young and adult chickens. During recent years fowl typhoid has increased

FIG. 185. Chickens showing effects of fowl-typhoid infection. (*W. J. Hall, Bur. Anim. Indus., U.S. Dept. Agr.*)

considerably, especially in certain commercial-broiler-producing areas. The disease occurs most frequently during the warmer seasons of the year Losses may amount to over 80 per cent among growing chickens and laying hens.

Fowl typhoid is caused by a microorganism called *Salmonella gallinarum* or *Shigella gallinarum*. Although the microorganism is readily destroyed by disinfectants and sunlight, it may persist for many days in dark, moist places and for several months in the carcasses of birds that died of fowl typhoid.

Typical symptoms of infected birds include dullness, ruffled feathers, paleness of the head, a drooping comb, loss of appetite, and a pale-orange-

colored diarrhea. A high temperature develops, giving rise to an acute thirst. Symptoms appear in 3 or 4 days after the birds become affected, and death usually occurs within 2 weeks. Post-mortem findings usually include enlargement of the liver, spleen, and kidneys. The liver is often mottled brick red in color with pale streaks, and the heart muscle has grayish nodules.

Fowl typhoid may be introduced into a flock by infected birds or infected material, such as shoes, coops, and litter, and thus the disease may spread from pen to pen and from farm to farm. Since a bird sick with fowl typhoid gives off millions of the microorganisms from the mouth and nose as well as through the droppings, every sick bird should be removed from the flock as soon as detected to keep the contamination of feed, water, and litter at a minimum. Very sick birds should be killed and burned or buried deeply.

The pullorum test (described later in connection with pullorum disease) for detecting breeding birds infected with the pullorum organism also detects many of the birds infected with the fowl-typhoid organism. It is necessary, however, to make additional agglutination tests to make sure of detecting all fowl-typhoid carriers in order to remove them from the flock. Some of the sulfa drugs have been found to lower mortality.

Infectious Coryza. This is probably one of the most commonly occurring diseases of chickens and has long been known by poultrymen as a "cold" or "roup." Infectious coryza is caused by the microorganism *Hemophilus gallinarum.*

The symptoms of infectious coryza include: (1) a bloody exudate in the nasal passages, frequently accompanied by an offensive odor; (2) inflamed and swollen eyes, the eyelids sometimes becoming stuck together; (3) the air passages become clogged with exudates, causing loud breathing.

In the case of growing chickens, growth is retarded, and in the case of laying flocks, egg production decreases. Since infectious coryza is readily transmitted from diseased to healthy birds, the former should be removed from the flock as soon as symptoms are observed. When an outbreak is suspected, one or more specimens should be taken or sent to the pathology laboratory to ascertain the presence of the organism.

Prevention of recurrences of the disease after its first appearance requires keeping the survivors of infected groups entirely separate from all other chickens or by killing them, the latter procedure being more effective. The poultry house and all equipment should be thoroughly cleaned and disinfected before new stock is placed in the house. Visitors and feed servicemen should not be allowed to enter the house or feed rooms.

The most effective measures of treatment and control include the use of sulfa drugs. For information on the proper method of administering sulfa drugs, a pathologist, veterinarian, or the manufacturer should be consulted.

FIG. 186. Infectious coryza. (Left, *C. M. Hamilton, Western Wash. Agr. Exp. Sta.;* center, *J. R. Beach, University of California, Dept. Vet. Science;* right, *A. Gannon, Ga. Agr. Ext. Service.*)

Pullorum Disease. This bacterial disease frequently causes enormous losses among chicks. It is caused by a microorganism called *Salmonella pullorum*, which infects the ovary of the hen, although it is also found in the intestinal tract of chicks.

The ovary of an infected hen presents a characteristic appearance. The partially or wholly developed yolks are angular in outline, shrunken, hard, and discolored to a dark-brown or greenish color. At times, yolks containing dark fluid are present.

Chicks that recover from the disease frequently retain *S. pullorum* in their bodies, where it later localizes in the active ovary. Some of the eggs laid by infected hens carry the microorganism, and chicks hatched from them spread the disease to others.

Nearly all the exposed chicks become infected, and the death rate may reach 100 per cent. The disease may be transmitted at hatching time if eggs from infected hens are incubated in the same incubator with other eggs. Another source of infection is through incubators and brooders that have previously held diseased chicks. Day-old chicks from infected flocks may carry infection to other chicks.

In the ordinary form of the disease in the adult hen, no external symptoms are observed, and it is only through the presence of the disease

in the chicks that attention is directed to its presence in the breeding stock.

In baby chicks hatched from infected eggs, the symptoms appear immediately after hatching or in a day or so. Chicks that contract the disease show symptoms 4 to 10 days later, and deaths occur from the time of hatching until about 3 weeks later.

Infected chicks frequently utter squeaky chirps and appear drowsy and ruffled, and the vent is sometimes smeared with fecal discharges.

Not only does pullorum disease cause heavy mortality among infected chicks, but also it has been demonstrated that the disease is responsible

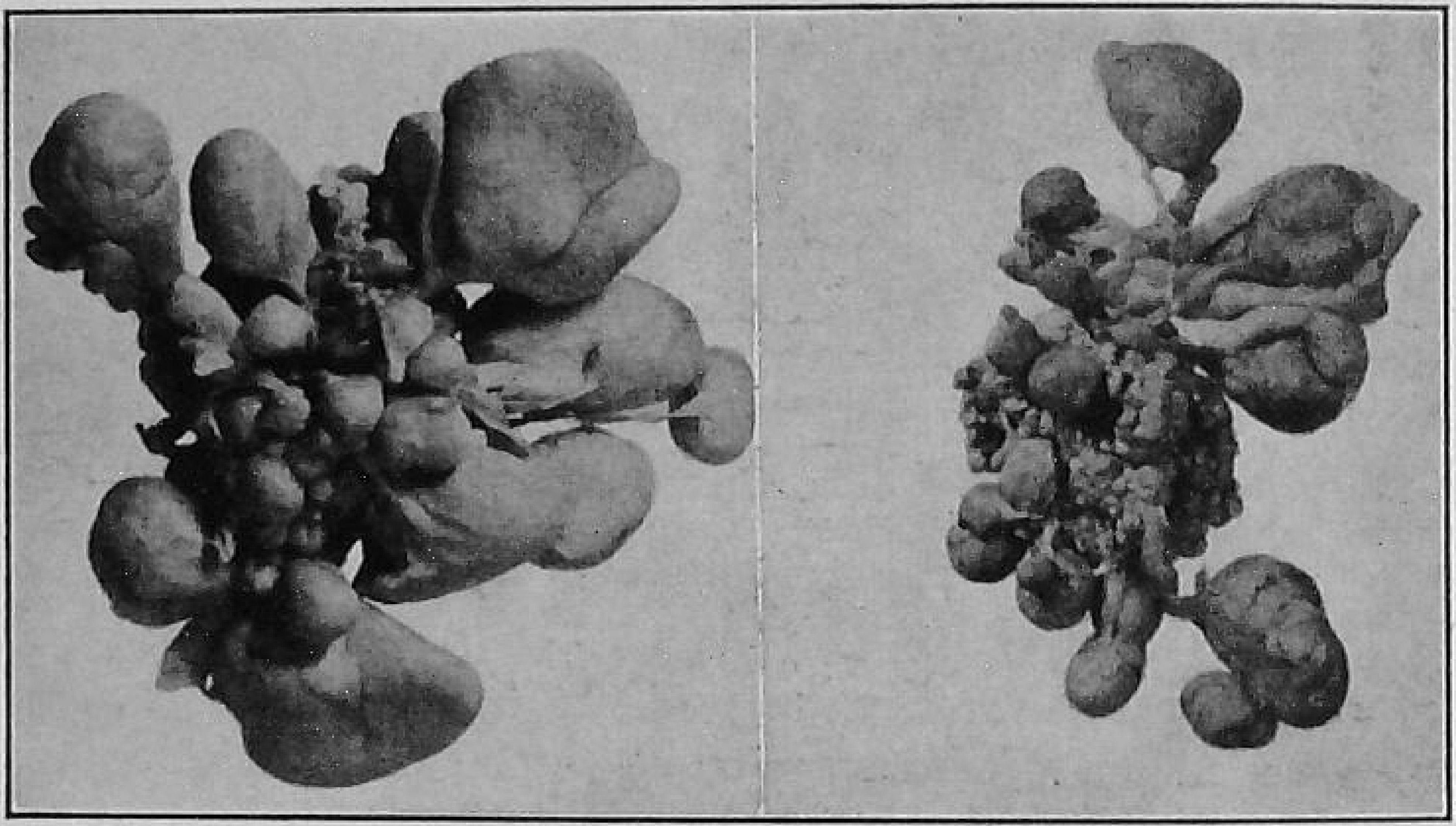

FIG. 187. Ovaries from two hens that are carriers of pullorum disease. Most of the ova are abnormal. (*Edwards and Hull.*)

for lowering hatchability by increasing embryo mortality during incubation. Results have been secured indicating that egg production is lowered when layers are infected with the microorganism causing the disease.

Controlling Dissemination. It is possible to carry out practical methods of control which serve the purpose or reducing mortality among chicks to the minimum. The identification of infected hens by a reliable test, their removal from the breeding flocks, the cleaning up and disinfection of the premises, and the disinfection of the incubators and hatching compartments constitute the minimum measures that must be undertaken to control the dissemination of pullorum disease.

Two reliable methods of testing include the tube-agglutination test and the rapid whole-blood-stained antigen test. Both tests are effective when properly performed, the whole-blood test being simpler and more practical, especially in states that have large numbers of breeding flocks,

many of them widely scattered. The eradication of the disease from every breeding flock should be the objective; this often means repeated testing of the same flock each year before all infected birds are eliminated.

The agglutination test is based upon the fact that in birds infected with *Salmonella pullorum*, certain substances (agglutinins) are formed in the blood which tend to cause the pullorum germs to clump together. These agglutinins or specific antibodies for *S. pullorum* are detected when the blood or blood serum is placed in contact with a pullorum antigen (a

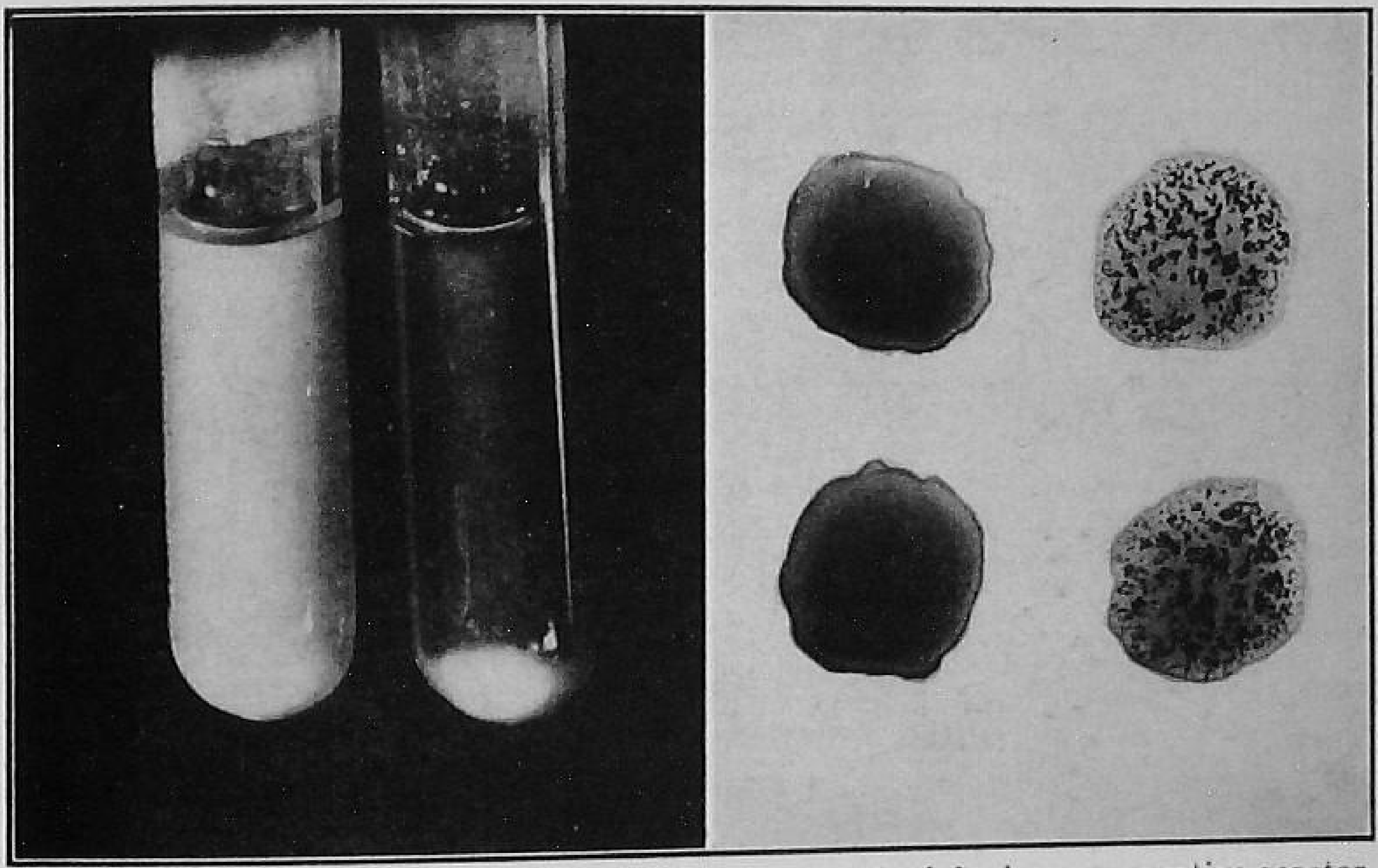

Fig. 188. Left, tube-agglutination test: the tube on the left shows a negative reactor, and the tube on the right shows a positive reactor. Right, the whole-blood agglutination test: the two mixtures on the left show negative reactions, and the two mixtures on the right show positive reactions. (*H. Van Roekel, Dept. Vet. Science, Mass. Agr. Exp. Sta.*)

suspension of killed pullorum bacteria which cause the disease); if the bird is infected, the dead bacteria clump together in the serum-antigen mixture.

In some sections of the United States and Canada, the pullorum-testing program is complicated by the presence of variant strains of *S. pullorum*. Under such circumstances, it is desirable to use variant tube antigens or polyvalent plate antigens whenever "breaks" occur in flocks shown to be free of pullorum disease by either regular testing method or whenever losses from pullorum infection among chicks are not eliminated by the two regular methods of pullorum testing.

Fumigation of Incubators. Although all breeding flocks should be tested and reactors to the test removed upon the completion of the test, it must be remembered that it is possible for birds to pass one test but

show later that they harbor the organism causing the disease. Also, mistakes in testing sometimes occur. It is important, therefore, in addition to testing breeding flocks, that incubators be properly disinfected in order to prevent any possible spread of the disease from infected to healthy chicks. Disinfecting the incubator is accomplished by fumigation. All hatchery operators should be familiar with the proper procedure for fumigating incubators, details of which may be obtained from authorities in charge of the pullorum-testing program in each state. Fumigation is not a substitute for testing.

VIRUS DISEASES

Some of the most important diseases affecting chickens are caused by filtrable viruses, organisms so small that they cannot be seen even under high-power magnification and pass through filters that retain ordinary types of bacteria.

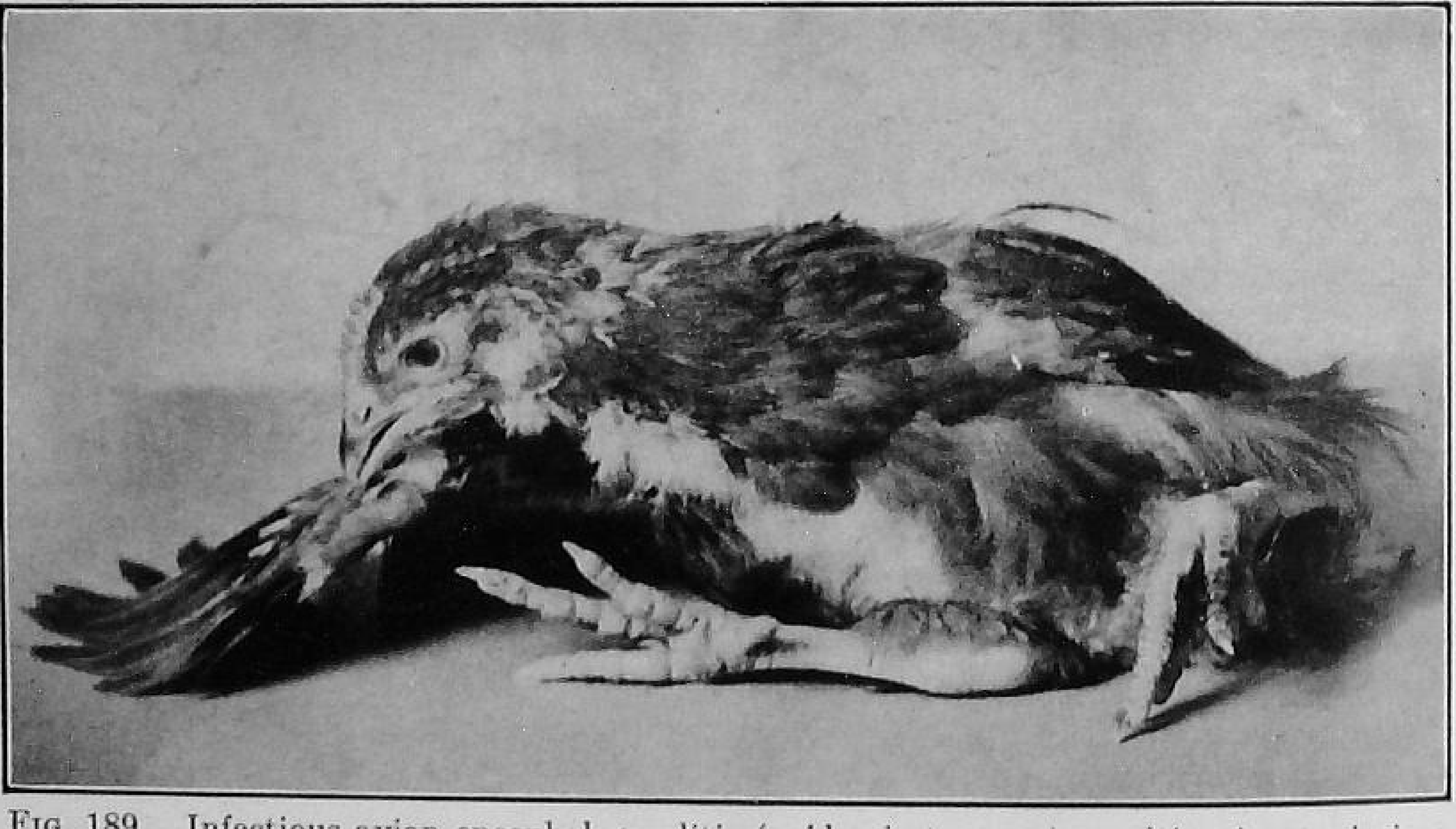

FIG. 189. Infectious avian encephalomyelitis (epidemic tremors) resulting in ataxia in a young chicken, which is attempting to right itself by using its wing. (*Photograph courtesy of P. K. Olitsky, from "Disease of Poultry."*)

Avian Encephalomyelitis (Epidemic Tremors). This disease of the nervous system of chickens is characterized by an unsteady gait due to inability to control movements of the legs, the brain being the principal seat of infection. There is also a pronounced trembling of the head. The disease usually makes its appearance between the first and sixth week after hatching. Infected chicks should be promptly removed from the flock since the spread of the disease is by direct contact. No satisfactory method of treatment has been developed. This virus disease should not

be confused with congenital tremor, which is inherited, or with nutritional encephalomalacia, which is due to a marked deficiency of vitamin E in the diet, such a deficiency rarely occurring when normal diets are fed.

Avian-leucosis Complex (Fowl Paralysis). Avian leucosis in its various forms is a disease of primary importance to poultry producers because it causes greater mortality in growing chickens approaching maturity and in adult fowls than most other diseases. The five forms of the disease are at present classified as follows: (1) lymphomatosis, including the neural, ocular, visceral, and osteopetrotic types; (2) erythroblastosis; (3) granuloblastosis; (4) myelocytomatosis; (5) sarcomatosis, or other tumors.

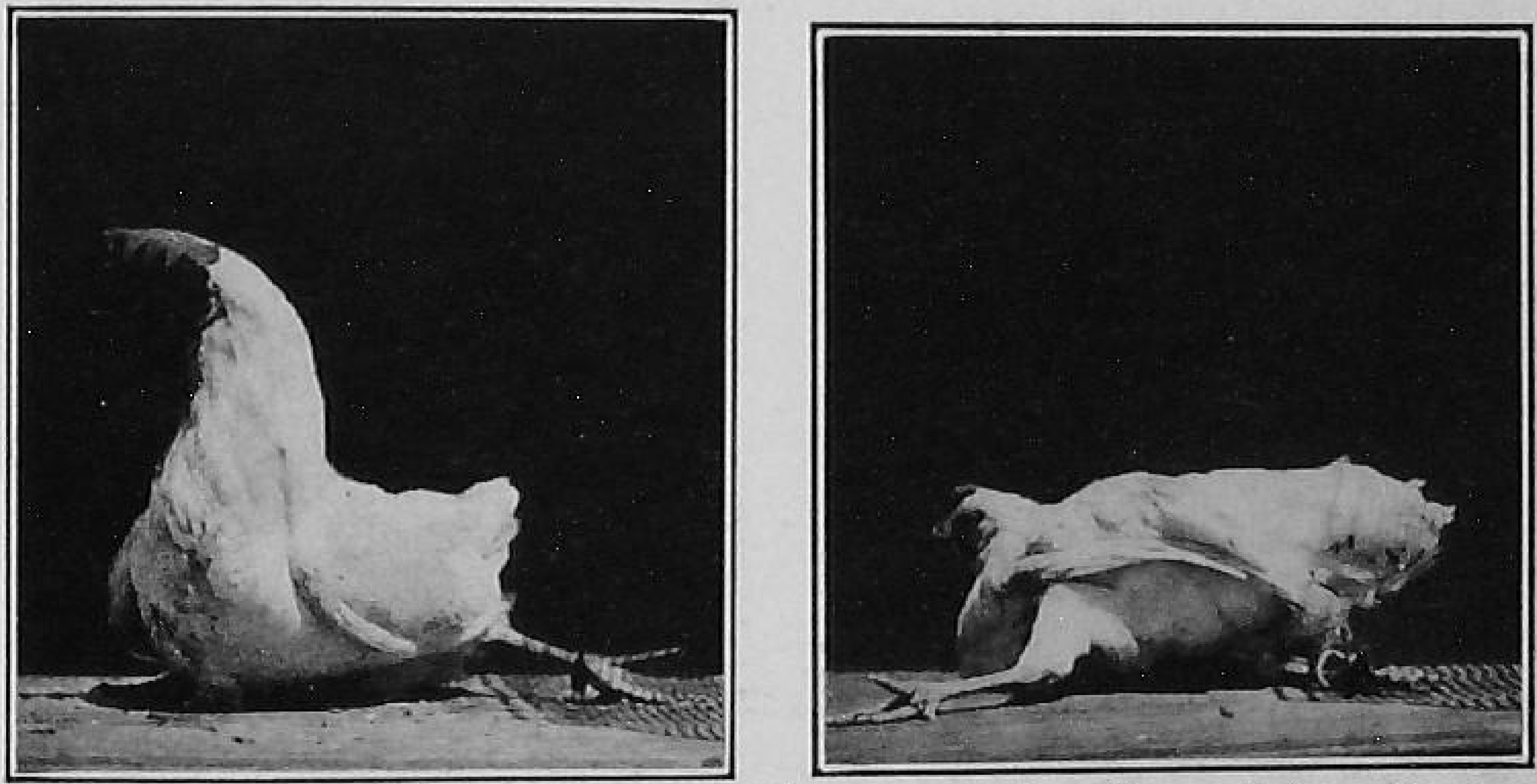

FIG. 190. Two birds suffering from neural lymphomatosis. (*Pappenheimer, Dunn, and Cone.*)

Neural Lymphomatosis. This form of the avian-leucosis complex primarily attacks young birds between 2 and 5 months of age and may cause high mortality. Typical symptoms include drooping of the wings and incoordination of the legs, one leg often being stretched forward or backward. When both legs are affected, the bird frequently sits in a squatting position and is only able to move with difficulty. The femoral portion of the sciatic nerve is commonly affected.

Ocular Lymphomatosis. The typical symptoms of this form of avian leucosis include blindness, or conditions recognized as "gray eye" or "white eye." The earlier stages of the disease are characterized by depigmentation and vascular congestion of the iris. The pupil of the eye becomes irregular, and the iris exhibits a grayish opacity with a tendency toward a pin-point pupil.

Visceral Lymphomatosis. In this form of avian leucosis, the viscera constitute the primary seat of infection, especially the liver, hence the

term "big-liver disease." Other organs of the body, including the kidney and ovary, are also affected, especially in the advanced stages of the disease. The comb becomes pale, there is loss of appetite, and infected birds gradually lose weight. Visceral lymphomatosis causes higher mortality than most other forms of the avian-leucosis complex.

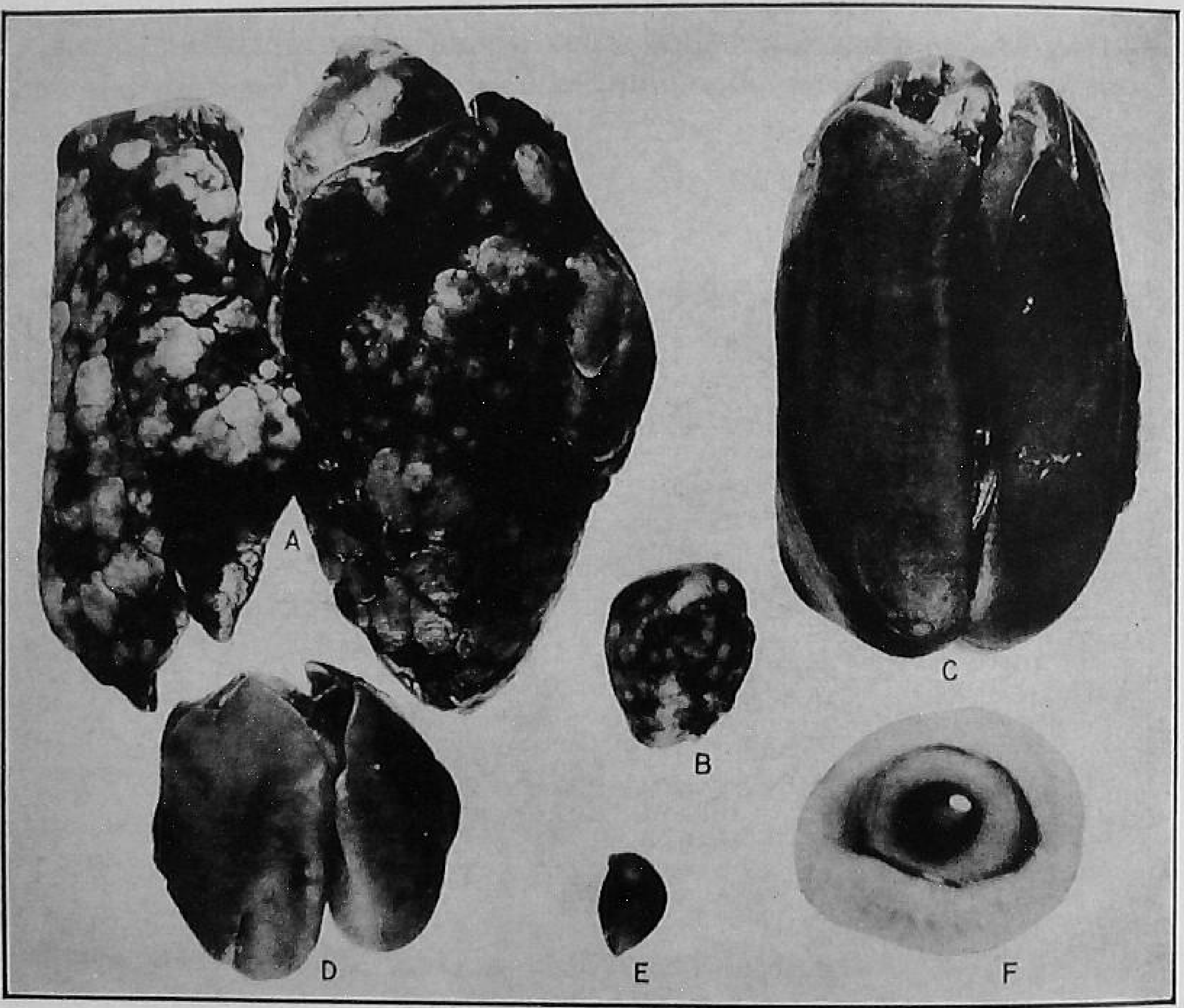

FIG. 191. (*A*) and (*C*) diseased livers from birds affected with visceral lymphomatosis. (*B*) spleen from an affected chicken. (*D*) and (*E*) liver and spleen from a healthy bird of the same age. (*F*) showing constriction and irregularity of the pupil of the eye of a chicken suffering from ocular lymphomatosis. (*U.S. Dept. Agr.*)

Osteopetrotic Lymphomatosis. As the name indicates, this is a form of avian leucosis affecting the bones, the long bones of the legs and wings being the noticeable parts of the skeleton affected. Diseased leg bones become irregularly thickened, hard, and inflamed.

The other four forms of the avian-leucosis complex, erythroblastosis, granuloblastosis, myelocytomatosis, and sarcomatosis, are relatively unimportant.

Treatment and Control. Various methods of treatment that have been employed to reduce losses from the avian-leucosis complex have been largely ineffective. Control measures with a view toward decreasing

losses include: (1) maintaining strictly sanitary quarters; (2) raising young chickens completely isolated from adult stock; (3) in so far as practicable, poultry breeders should maintain a closed-flock system of breeding and keep their premises quarantined; (4) poultry breeders should select breeding stock each year from among families of full brothers and sisters showing the lowest incidence of the avian-leucosis complex; (5) it would be advisable to incubate eggs from selected resistant families separate from all other eggs; (6) farmers, hatchery-flock owners, and

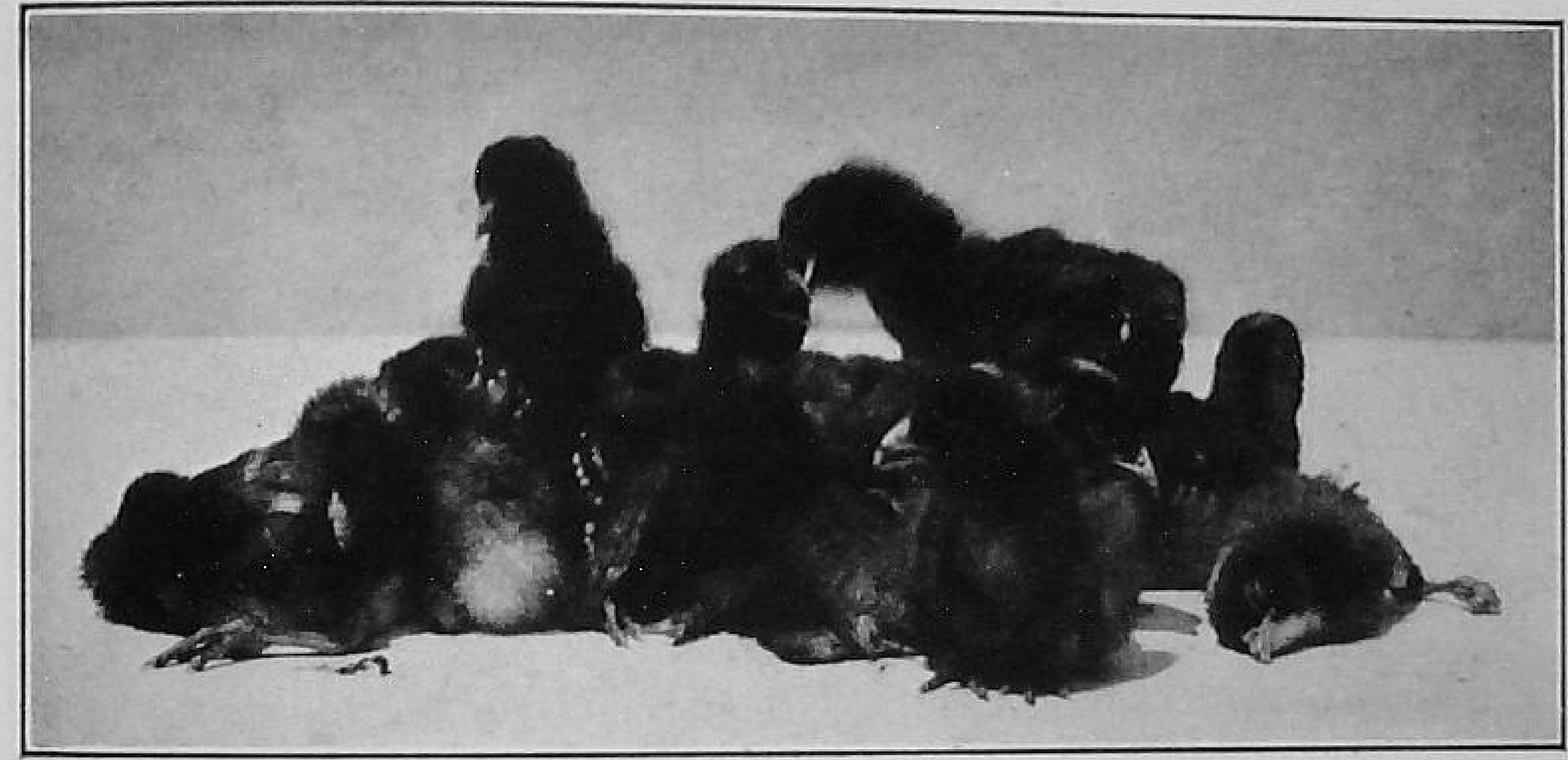

FIG. 192. Chicks suffering from infectious bronchitis. (*R. Graham, University of Illinois Dept. Vet. Science.*)

commercial poultrymen should secure chicks from poultry breeders who make a practice of breeding for resistance to the avian-leucosis complex or from poultry breeders whose flocks are relatively free of the disease; (7) all poultrymen should cull all birds affected with any form of avian leucosis as soon as they can be detected.

Infectious Bronchitis. This respiratory disease is caused by a filtrable virus which may attack birds of all ages, including growing chickens and susceptible laying hens. The mortality in growing chickens may be up to 90 per cent, which means that this disease is sometimes a serious menace to commercial-broiler producers. In laying flocks, an outbreak of infectious bronchitis often results in a marked decrease in egg production. When egg production is resumed at a normal level, many of the eggs produced are liable to be abnormal in shape and have poor shell texture.

The outstanding symptom of the disease is gasping, the beak being extended upward and opened wide at each expiration, sometimes accompanied by convulsive coughing. Among growing chickens, the disease usually occurs before the chickens are 4 weeks of age and may spread

very rapidly. The lungs become congested. The disease spreads quickly to healthy birds by direct or indirect contact. This is one reason why the purchase of started chicks from a hatchery is not advised, numerous outbreaks having been traced to started chicks reared in brooder batteries for a few weeks in infected hatcheries. Since the symptoms resulting from infectious bronchitis are somewhat similar to those resulting from infectious coryza and laryngotracheitis, a competent poultry pathologist or veterinarian should be consulted for diagnosis.

There is no known satisfactory cure for infectious bronchitis. The only practical suggestion that can be offered to poultrymen whose flocks

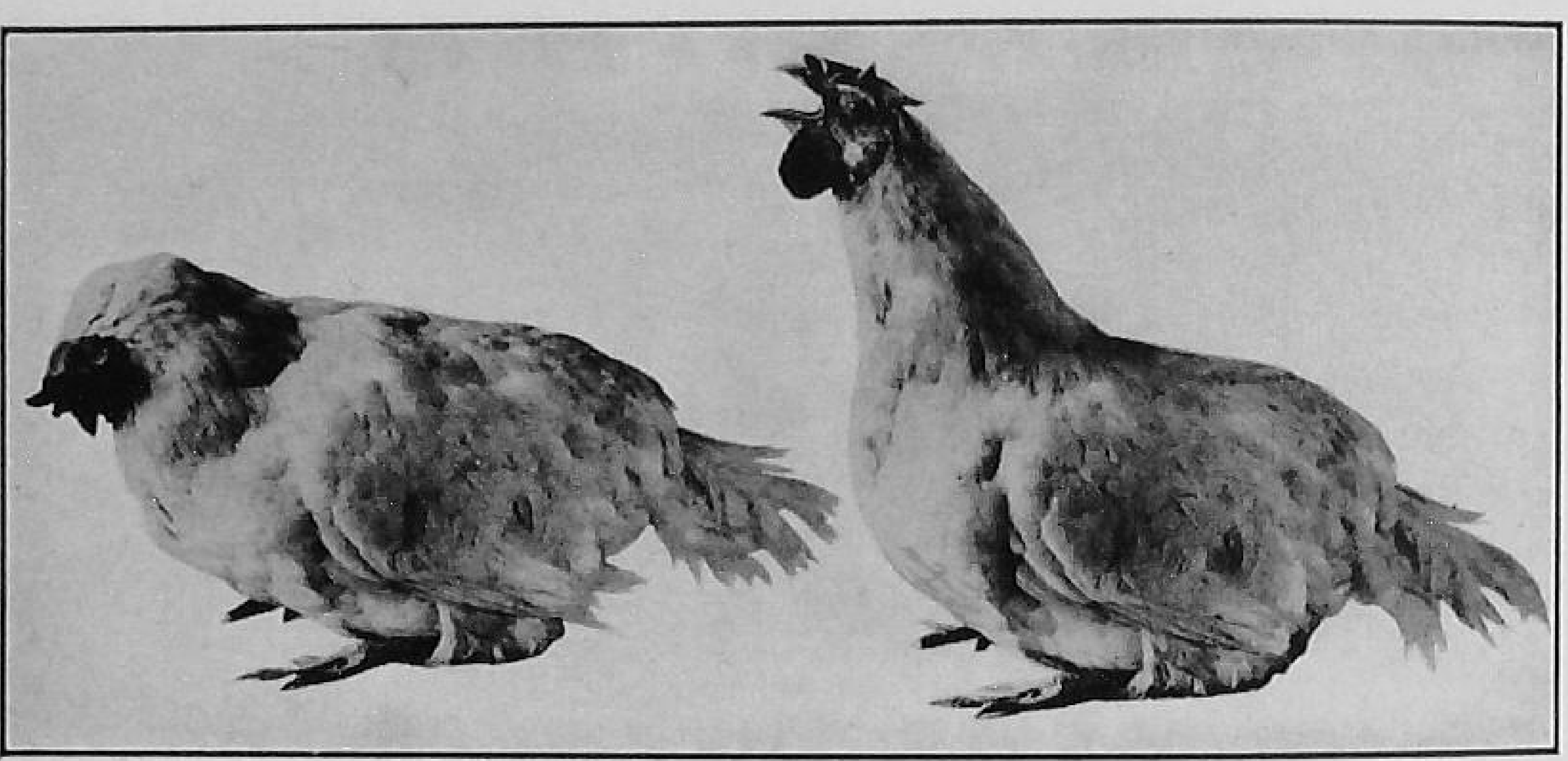

FIG. 193. An advanced case of infectious laryngotracheitis. Left, showing position during expiration. Right, showing position during inspiration. (*J. R. Beach, Dept. Vet. Science, Calif. Agr. Exp. Sta.*)

suffer an outbreak of infectious bronchitis is to dispose of the birds as soon as possible and thoroughly clean and disinfect the poultry house and equipment before putting chicks or adult birds in the house.

Infectious Laryngotracheitis. At first this disease was termed "infectious bronchitis," but inasmuch as it was shown later that the larynx and trachea, or windpipe, were the principal organs infected, the disease has been recognized as "infectious laryngotracheitis." This respiratory disease may cause very high mortality among birds from 5 to 10 months old. Birds that recover may be carriers of the organism.

The principal and characteristic symptom of infectious laryngotracheitis is gasping; during inhalation the head is extended upward with the mouth wide open, and during exhalation the mouth is lowered with the mouth closed. Rattling, gasping, and gurgling sounds in breathing are characteristic, although a number of birds may die before typical symptoms are recognized. There may be a slight watery discharge from the eyes and nostrils, and in a few days birds may show labored breath-

ing. Even though mortality in a laying flock is not very high, the losses from decreased egg production often exceed the direct losses from mortality.

Vaccination. When a flock has been exposed to the disease, as in the case of pens of birds on a farm or commercial-poultry plant adjacent to a pen on the same premises where an outbreak has occurred, or in the case of a flock in a community where the disease is prevalent, vaccination should be undertaken to prevent the spread of the disease. On farms where the disease has occurred and where some of the survivors are held over, the young birds should be vaccinated.

Vaccination consists of brushing the cloacal mucous membrane with a vaccine prepared from the membranes of artificially infected embryos. Vaccination should be done before the birds are 4 months old. Since the live virus is used and since it may cause the disease to break out in virulent form, great care must be exercised in applying the vaccine. A successful "take" is indicated by a swelling of the lips of the cloaca, redness and swelling of the mucous membrane, and the presence of mucus with blood on its surface. The birds should be examined on the fifth day after the flock has been vaccinated, those not showing a definite "take" being revaccinated immediately.

Fowl Pest or Fowl Plague. Fowl pest is an acute, highly infectious disease of chickens that usually causes very high mortality. Although occurring rather frequently in Europe, there have been only two extensive outbreaks in the United States.

The disease appears very suddenly, some birds dying before showing symptoms of the disease. The general symptoms include: dullness, weakness, ruffled feathers, swollen head, dark eyes, eyelids closed, a tendency to remain on the roost or in a secluded place, and a staggering gait while walking. Egg production ceases, and body temperature may rise to 110 to 112°F. Mucus exudes from the nostrils, and there is sometimes profuse and watery diarrhea. Death usually occurs within 2 or 3 days.

Since there is no cure for the disease and since one infected bird introduced into a flock may cause a serious outbreak, poultrymen should be warned against importing birds from foreign countries unless given permission by the proper authorities. The imported birds should be kept isolated until proved to be free of the disease. Whenever an outbreak of fowl pest occurs, complete eradication of all birds in the flock is necessary, followed by thorough cleaning and disinfection of the poultry house and equipment.

Fowl Pox. This is a highly infectious skin disease characterized by typical pox lesions in the form of wartlike scabs on the face, comb, and wattles. Also, in many cases there is an accumulation of cheesy exudates

on the mucous membranes of the mouth and larynx, a condition often referred to as "avian diphtheria."

The fowl-pox virus establishes itself and produces lesions where the cells of the skin or mucous membrane suffer damage through cuts, bruises, or scratches. Mosquitoes may also transmit the disease by feeding on the lesions of an infected bird followed by feeding on a susceptible bird.

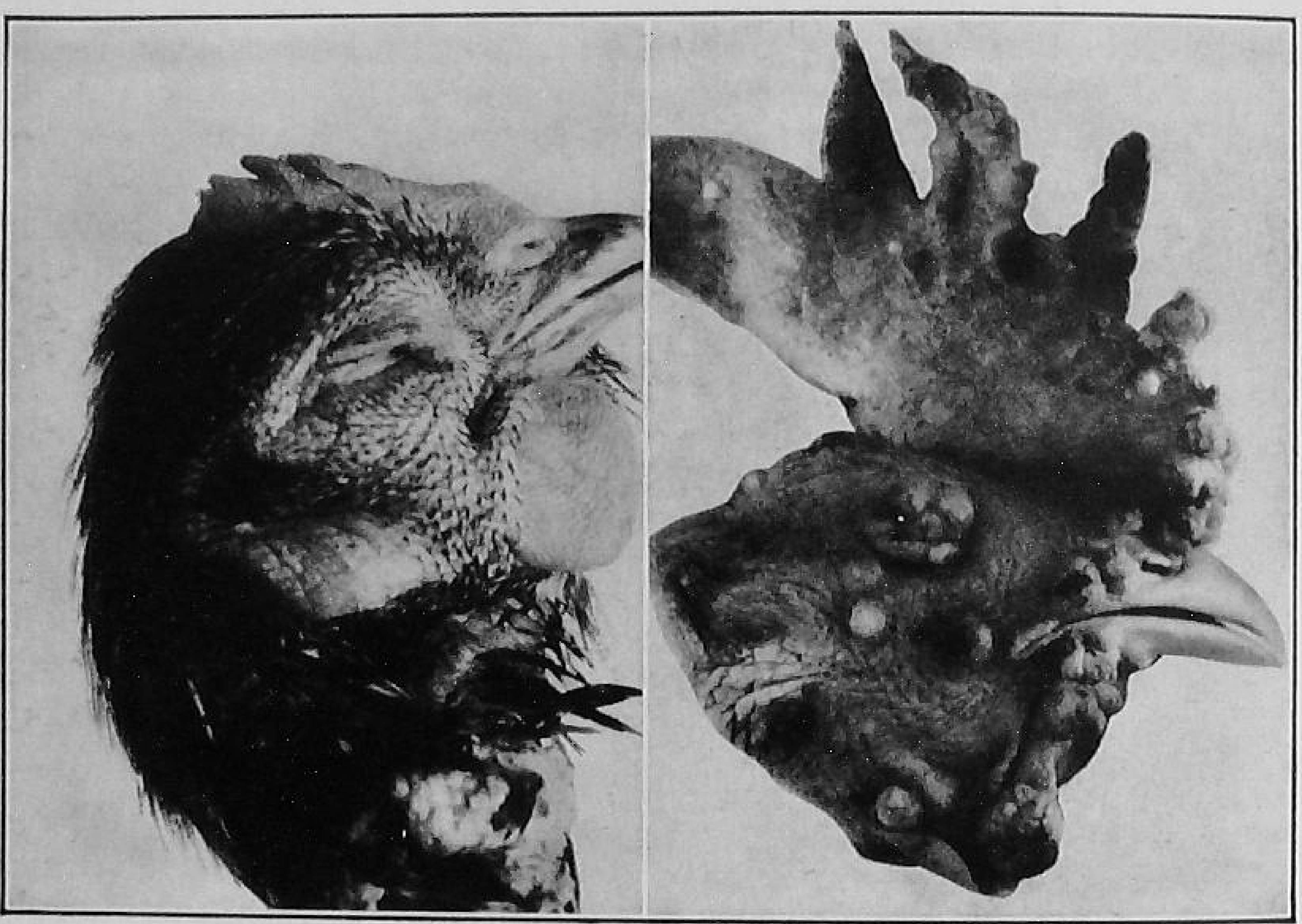

FIG. 194. Left, the head of a chicken suffering from fowl pest: note the swollen face, ear lobes, and wattles. (*E. L. Stubbs, University of Pennsylvania, School Vet. Med.*) Right, the head of a chicken suffering from fowl pox: the lesions are numerous and affect the eyes as well as other parts. (*E. M. Dickinson, Ore. Agr. Exp. Sta.*)

Fowl pox is most commonly encountered in the fall and winter months, hence nearly full-grown chickens and adult birds are the customary victims. Monetary losses from decreased egg production are usually greater than losses from mortality. In recent years, however, the occurrence of fowl pox among flocks of broilers has shown a tendency to increase.

Vaccination. There is no satisfactory treatment for fowl pox, but vaccination, when properly carried out, is a satisfactory preventive. There are two kinds of vaccines, fowl-pox vaccine and pigeon-pox vaccine, the former being preferable because it produces more lasting immunity. Pigeon-pox vaccine may be used for vaccinating chicks reared as broilers. The virus for fowl-pox vaccine is produced by propagation on the skin of healthy susceptible chickens or on the chorio-allantoic membranes of

developing embryos. Either vaccine provides protection against natural fowl pox. Vaccination should not be done unless the birds are healthy.

The vaccine may be introduced into the skin by the "feather-follicle" or by the "stick" method. In the "feather-follicle" method, two or three feathers are plucked from the skin and with a brush a very small quantity of vaccine is applied to the feather follicles. In the "stick" method, a specially made needle is dipped into the vaccine and then the skin is punctured with the needle, the feathers on one side of the leg

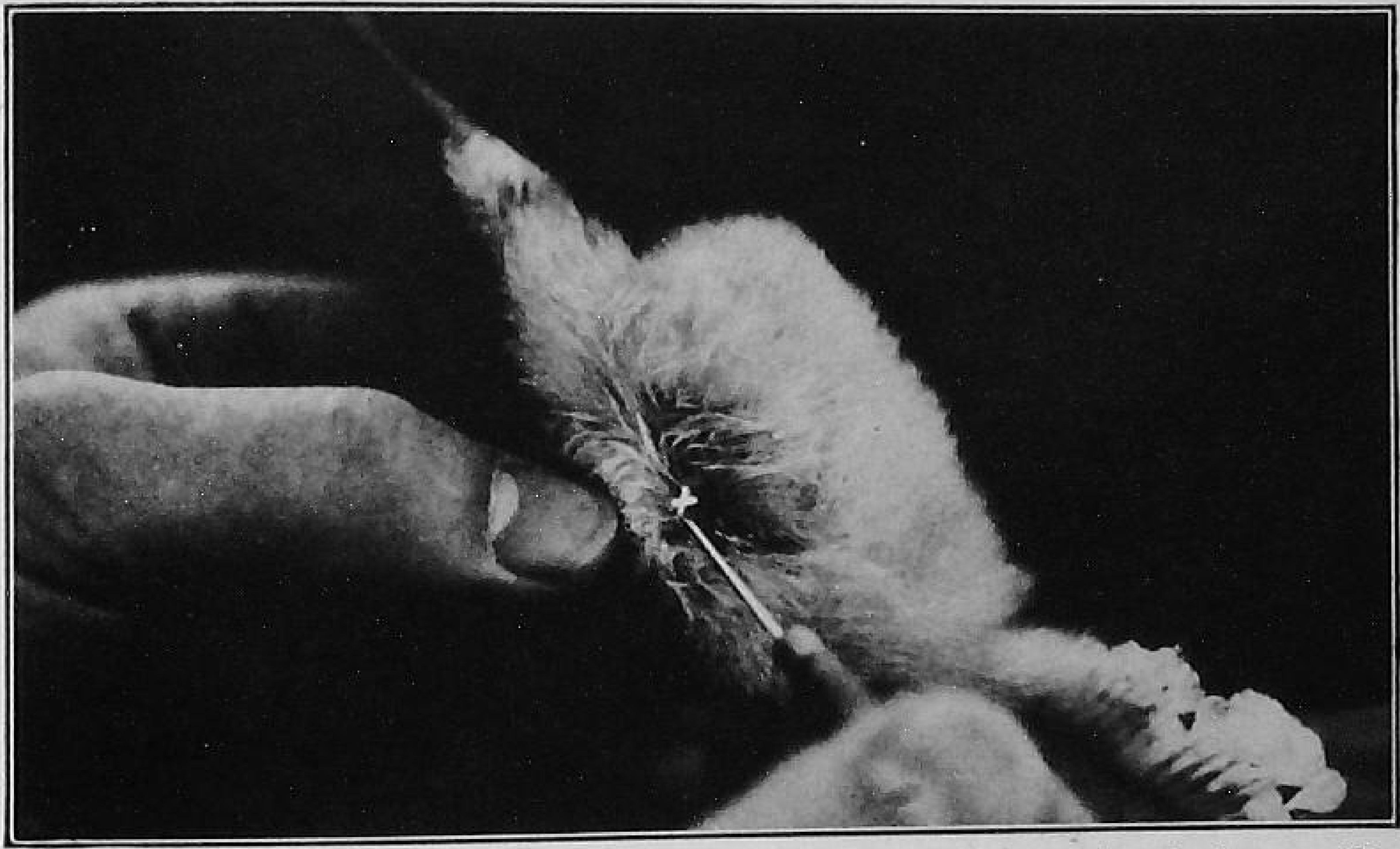

Fig. 195. Showing the preferred site for vaccinating baby chicks against fowl pox. The site is in the fold of the flank in front of the joint between the femur and the tibiotarsus. (*E. M. Dickinson, Ore. Agr. Exp. Sta.*)

having been previously removed. A simpler and quicker procedure is to stretch the bird's wing out and pierce the web from the underside. Except for broilers, the best time to vaccinate is between 8 and 16 weeks of age, and always at least 2 months before pullets will commence laying. For preventing an outbreak of fowl pox among broilers, baby chicks may be vaccinated between 3 and 7 days of age. The preferred site for vaccinating baby chicks is in a fold of the skin of the flank in front of the joint between the femur and the tibiotarsus.

In order to determine whether the vaccination of a flock has been successful, the flock should be examined for "takes" about 7 to 10 days after vaccination. A "take" is indicated by inflammation followed by the formation of a scab. If one-fifth or more of the members of the flock show no evidence of "takes," the entire flock should be revaccinated immediately.

Vaccination annually is advisable in flocks that have suffered from fowl-pox infection and in flocks in a thickly populated area where the disease is prevalent.

Newcastle Disease or Avian Pneumoencephalitis. This disease (pneumo-encephal-itis) is a highly infectious respiratory disease caused by a virus that also affects the nervous system. Although the disease may occur at any season, it occurs most frequently during the fall, winter, and spring. Among growing chickens, mortality is apt to be quite high, and survivors are retarded in growth. Among laying flocks, mortality may vary from almost nothing to almost 100 per cent, apparently depend-

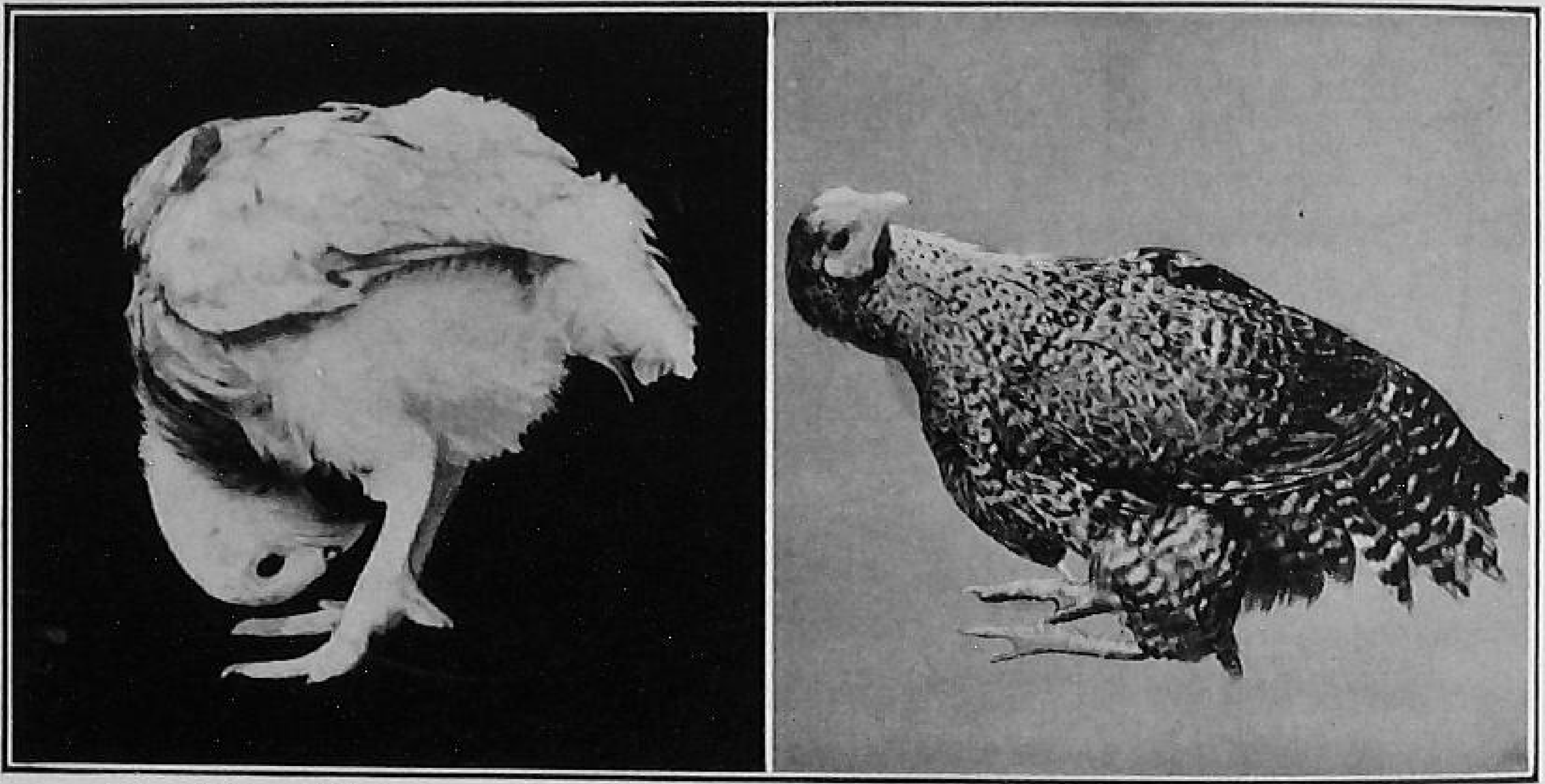

Fig. 196. Chickens suffering from Newcastle disease. (*Lederle Laboratories.*)

ing among other things upon the virulence of the organism. Egg production suffers greatly, often declining to almost zero within 4 days after the flock becomes infected. Normal egg production may be resumed in about 6 weeks, but many of the eggs are misshapen and have rough shells and breeds that normally lay eggs with brown shells now produce eggs with bleached shells. Albumen quality is also affected.

Among young chickens, the first symptoms include gasping, coughing, and sneezing; and as the disease advances, nervous symptoms become manifest. Some birds may sit on their hock joints, others may walk backwards or in circles, and still others hold their heads over their backs or between their legs. The combination of respiratory and nervous symptoms in young birds is a characteristic symptom of Newcastle disease. Among adults, the symptoms are largely of a respiratory nature plus a sudden decrease in egg production. There is usually a loss of appetite, and some birds become droopy. If the infection is severe, most of the members of the flock sit around on the floor or on the roosts.

A positive diagnosis of Newcastle disease should be based only on laboratory findings. In case of a suspected outbreak, the birds to be diagnosed should be taken to the laboratory by private carrier.

Vaccination. There is no satisfactory treatment for the disease. It may be controlled, however, by vaccinating a flock with a properly prepared strain of virus that does not harm the bird but establishes immunity. The "stick" method is employed, the innoculating needle being dipped into the mixed vaccine and then pushed through the web of the wing from the underside. Vaccination should be carried out in flocks where the disease has appeared previously and in flocks not previously infected but located in communities where the disease is prevalent. Breeding stock immune to the disease usually pass immunity on to their chicks, which are thus protected up to about 4 weeks of age. After this temporary immunity period has passed, the chicks should be vaccinated. This is important for broiler producers.

In the case of farm and commercial-poultry flocks that have been exposed to Newcastle disease, vaccination should be carried out after the birds are 4 or 5 weeks old, but always at least 1 month before pullets commence laying. All susceptible birds on the premises should be vaccinated. However, vaccination is not recommended if the flock is suffering from parasitic infestation or from such diseases as bronchitis, coccidiosis, or laryngotracheitis. When vaccination of a flock is necessary, the flock owner should follow the directions of the manufacturer of the vaccine.

OTHER DISEASES

There are a few other diseases of economic importance to many poultrymen, but none of them are so serious from a nationwide standpoint as those which have been discussed previously.

Avian Monocytosis. Occurring most frequently among pullets between about 5 and 7 months of laying, this disease has been called "blue-comb" or "pullet disease," the comb usually turning dark in color. The disease is apparently of metabolic origin and occurs more frequently in general-purpose breeds than among Leghorns. In addition to the darkening of the comb, affected birds become depressed, lose appetite, and have watery or whitish diarrhea. If the pullets have commenced laying, there is a sudden decrease in egg production. Mortality may range from zero to about 50 per cent, but in most cases the greater loss is due to decreased egg production. The disease often runs its course in about 2 weeks, although normal level of laying may not be resumed for several weeks.

Pathologically the disease results in dehydration of the skeletal mus-

cles, necrosis of the liver and pancreas, increased mucus in the intestine, enlarged kidneys accompanied by uric nephritis or visceral gout, and changes occurring in the blood picture, the latter resulting in the adoption of the term "avian monocytosis."

Since the cause of the disease has apparently not been definitely established, suggestions concerning successful treatment and control are meager. Among other things, plenty of clean water should always be available, cool quarters should be provided, and wheat and other scratch-grain consumption should be limited. Molasses may be given in the drinking water at the rate of 5 per cent or a mash mixture comprised of equal parts of bran and ground oats plus 20 per cent molasses fed in a crumbly state. For treating large-sized flocks, the use of potassium chloride is much simpler. One level tablespoonful per gallon of water should be given for 1 week or a grade of muriate-of-potash fertilizer containing at least 60 per cent of K_2O may be used in the water at the rate of 0.5 per cent for 1 week. If the outbreak is severe, a mash mixture containing 1.5 per cent muriate of potash should be fed for an additional week.

Staphylococcosis. Chronic arthritis is the outstanding characteristic of this disease, which affects growing chickens. The joints become swollen and are hot and tender. Affected birds sometimes rest on their hocks. In some cases about 50 per cent of the affected birds may die, but in less severe cases recovery may take place in about 2 weeks. Prevention consists of taking every precaution to avoid mechanical injury to birds, since such injury may be the mode of entry for the organism causing the infection. Treatment with penicillin is effective.

MINOR DISORDERS AND OTHER CONDITIONS

Certain minor disorders and other abnormal conditions are discussed briefly because, in some cases, prevention or treatment is fairly simple.

Bumblefoot. When the bottom of the foot is badly bruised or cut, an abscess may develop. To treat this, the scab may be removed, the pus forced out, applications of an antiseptic solution applied, and the foot bandaged.

Frozen Comb and Wattles. In extremely cold weather in northern sections of the country, the combs and wattles of birds sometimes become frozen, especially if the laying house is not properly insulated and ventilated. If many birds in the flock are affected, both fertility and egg production may decrease. Thaw out affected parts and rub them with vaseline.

Frozen combs and wattles may be avoided by dubbing them. This is a common practice on the part of a few poultrymen. Dubbing is usually done at about 3 months of age, although the combs and wattles

of baby chicks may be dubbed. With chicks, sharp scissors are usually used. With older birds, scissors or tinner's shears are used. Excessive bleeding is avoided by laying a feather or sprinkling flour or fine mash over the cut surface. Dubbing by the use of the electric cautery is probably the best method to follow to avoid excessive bleeding.

Crop Impaction. Sometimes the crop of a chicken or hen becomes impacted with feed and greatly distended. If the crop is not too firmly impacted, it is sometimes possible to correct the trouble by giving the bird water, and then by holding the head downward, the feed may be forced out through the mouth by massaging the crop.

Otherwise, the feed must be removed from the crop by making an incision in the skin over the crop and in the wall of the crop. A 1-in. incision is made on the upper front surface so that it will be on the top side of the drop when the bird is standing. After the contents of the crop are removed, wash it out with warm water. Sew up the incisions in the skin and wall of the crop separately with white silk or cotton thread. Withhold feed and water for several hours, the first feed given being a moistened mash.

Poisoning. Mortality or sickness from poisoning often occurs when chickens eat poisonous plants, seeds, or other materials gleaned from the fields or are fed certain feeds or other materials that have toxic properties. Normal diets or commercial-feed mixtures rarely poison.

The poisonous effects of selenium have been demonstrated in the feeding of grains grown on certain types of alkali soils in South Dakota and adjacent regions; this subject has been discussed in the chapter on Incubation Principles and Practice. Rose chafers are poisonous to chicks up to 10 weeks of age, 15 or 20 chafers being sufficient to kill a week-old chick. Occasionally chickens encounter drugs or chemicals that are poisonous, *e.g.*, arsenic used for the poisoning of rats and grasshoppers, kamala in excessive amounts, lead contained in paint skins, nicotine sulfate in excessive amounts, phosphorus contained in rat poisons if consumed in considerable quantities, and potassium permanganate if consumed in any appreciable quantity.

The more important sources of plant and seed poisoning include: (1) leaves of the black locust; (2) corn-cockle seed, if consumed in excess of 0.25 per cent of the bird's body weight; (3) cottonseed meal, the poisonous principle of which is gossypol, is toxic if fed in very large amounts; (4) the coyotillo plant is toxic in doses of 0.3 per cent of the live body weight; (5) crotalaria seed, produced by the species *Crotalaria spectabilis*, which is grown in some Southern states as a legume; (6) daubentonia seed, from an ornamental shrub grown in the Gulf states; (7) milkweed, sometimes eaten by poultry when other green plant material is not available; (8)

the nightshade and berries; (9) lupine seeds in excessive amounts; (10) the green sprouts of potatoes; (11) tobacco, sometimes added to mashes as a vermifuge, is toxic in its effects in excessive amounts.

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CHAPTER 12

MARKETING EGGS

Approximately 94.5 per cent of the annual egg crop is disposed of through market-egg channels and about 4.5 per cent is used to produce chicks. Practically all the market eggs are used for human consumption except those which become inedible. Some of the inedible eggs are used in the preparation of certain animal feeds and for certain industrial purposes. In addition, all too high a proportion of each year's egg crop is lost through breakage.

The problem of most wisely and efficiently disposing of the enormous number of market eggs produced each year is one of vital interest to producers because egg prices and profits are involved. The first requisite in the marketing of eggs to best advantage is the production of eggs of the highest possible quality. The second requisite on the part of the producer is to take every possible precaution to maintain the original quality of the fresh-laid egg. Then from the time eggs leave the producing plant until they reach the consumer's table, they must be given the best possible care to maintain, in so far as possible, their original quality. Buyers and sellers of eggs, including wholesalers and retailers, are interested in the various processing and distributing factors that affect egg quality, for the simple reason that there is less wastage in marketing eggs of good quality than in marketing those of poor quality. Consumers want eggs of good quality or, in many cases, none at all.

The term "quality," when applied to market eggs, means that condition of shell and contents of eggs which give the greatest satisfaction to the consumer. There are many factors that affect the condition of the shell and egg contents, including the methods of collecting, storing, and handling, the ultimate quality determining, to a considerable degree, consumer demand and prices paid.

QUALITY IN FRESH-LAID EGGS

The egg is a highly perishable product and, if not given proper care between the time it is laid and the time it is consumed, may deteriorate markedly in several respects. Quality is at its best in fresh-laid eggs because at that time they have their greatest nutritive value as an article of food for humans. Therefore, before discussing the various factors

that tend to lower egg quality, it is well to consider the characteristic quality of fresh-laid eggs.

Yolk and Albumen Quality. Dealers in eggs resort to candling for the purpose of grading eggs according to interior quality, but housewives judge the quality of eggs by the appearance of the yolk and albumen or white when the shell is broken and the contents dropped into a dish or frying pan.

When the contents of a normal fresh egg are dropped into a dish, the yolk and thick white stand up well, while the thin white spreads out over

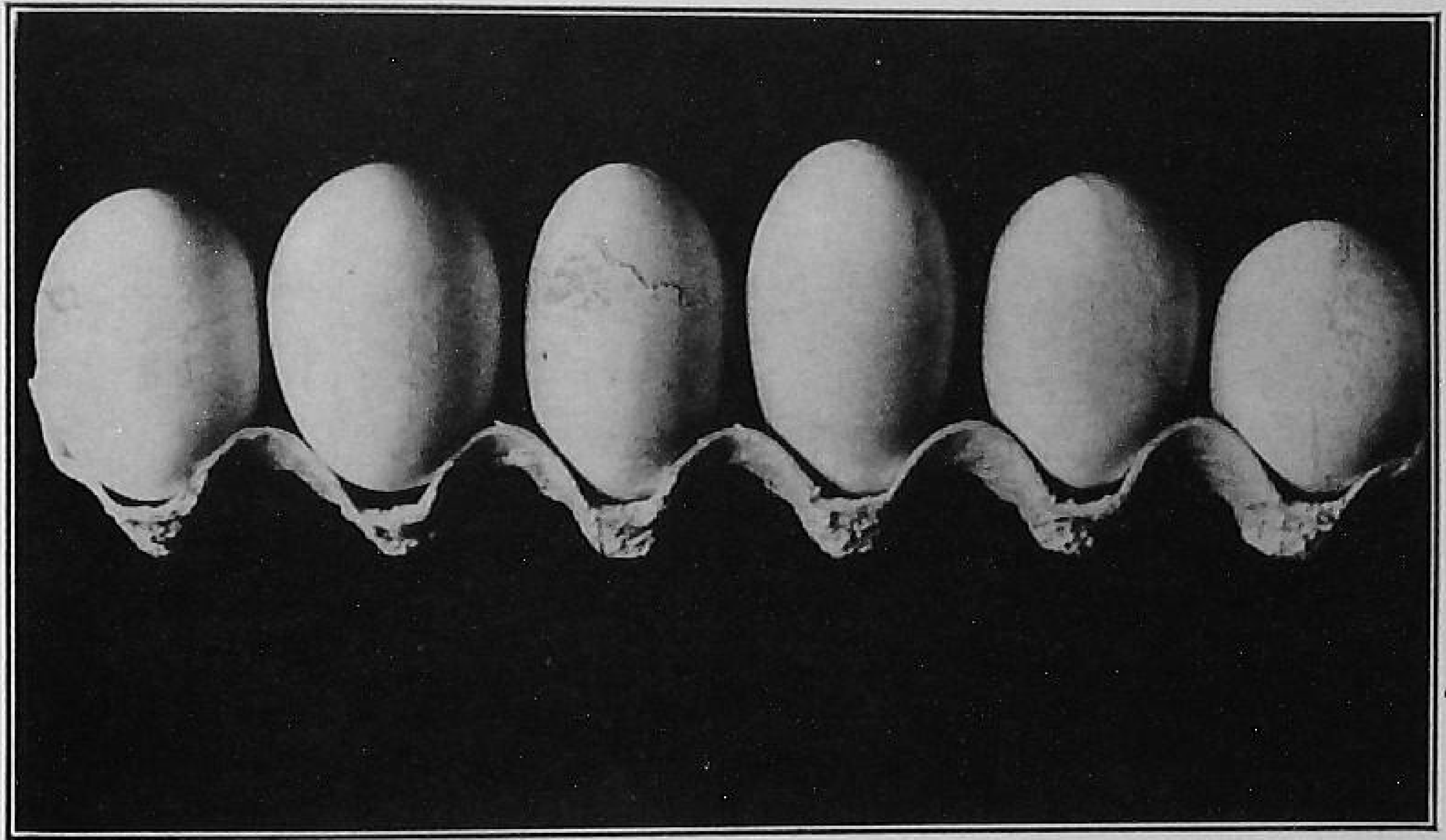

FIG. 197. Eggs with cracked and rough shells and eggs of irregular shape should be kept out of marketing channels. (*E. S. Snyder, Ontario Agr. Coll.*)

a relatively small portion of the plate. When a stale egg is broken open, the yolk and thick white appear flattened, and the thin white is so watery that it may cover the entire plate. Between these extremes are many gradations of change in the condition of the yolk and egg white.

Size and Shape. The standard size of market eggs is 2 oz. or 56.7 g. per egg. Eggs weighing between 1⅞ and 2⅛ oz. fit best in the standard fillers used in egg cases. Eggs averaging larger than 24 oz. per doz. may command more than eggs weighing 24 oz. per doz., but extra large-eggs are discriminated against because of danger from breakage and irregularity of production. Each dozen or case of eggs should be reasonably uniform in size in order to command the best price.

The factor of uniformity of egg shape is of some importance, extremely long eggs tending to increase breakage when they are packed and transported in cartons and cases.

Shell Color and Texture. In most markets there is neither a preference for brown nor a preference for white eggs, but in all markets it is important that a dozen or a case of eggs be uniform in color. In the case of white eggs it is especially important that the eggs be free of tints. New York City enjoys the reputation of being a white-egg market, although in the last few years brown eggs have been known to top the market at different times. Boston has always had the reputation of being a brown-egg market.

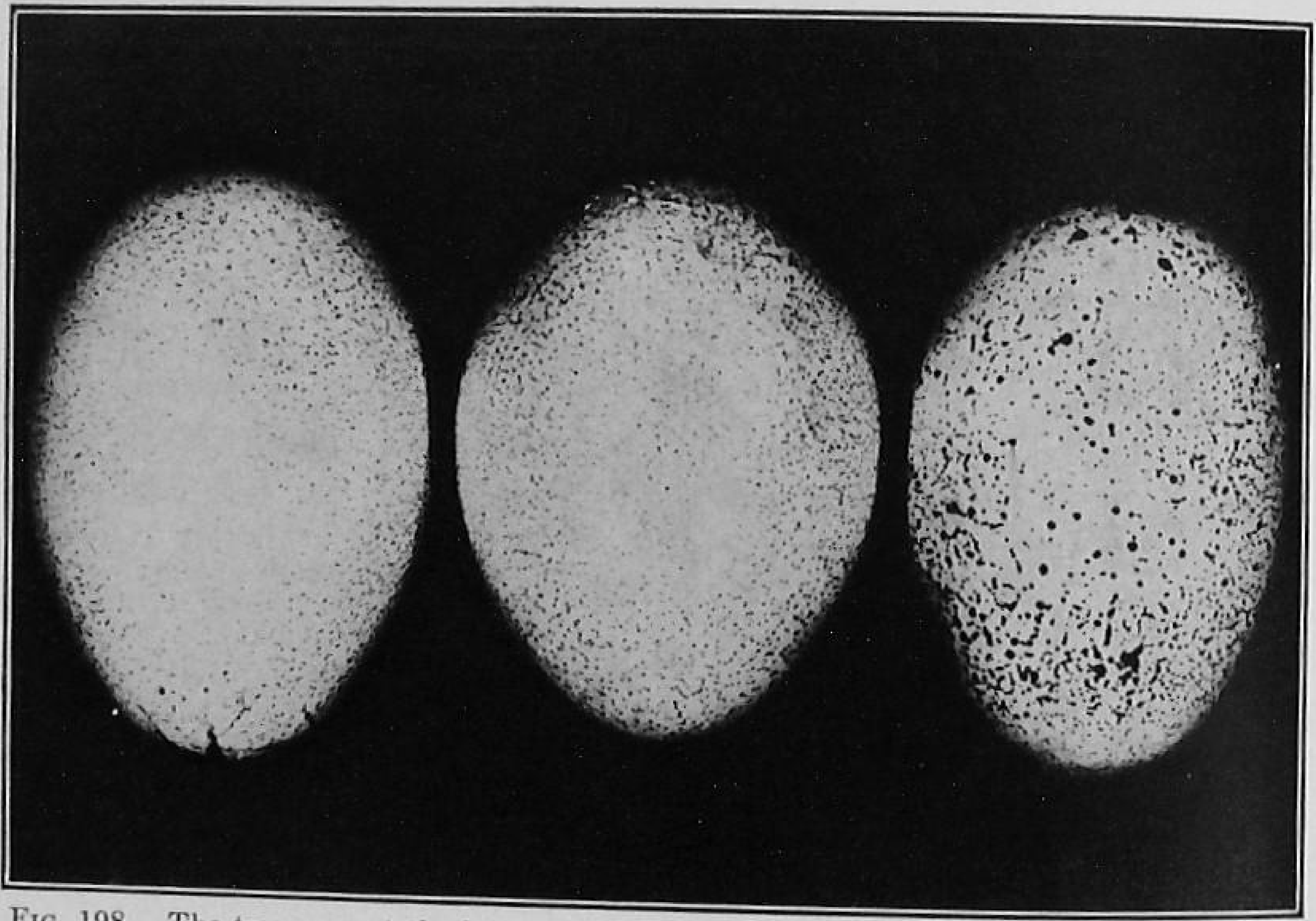

FIG. 198. The two eggs at the left have strong, thick shells. The egg at the right has a thin, porous shell. The pores of these shells were made visible by scraping the inside of the shell, which was then filled with a dye. (*E. S. Snyder, Ontario Agr. Coll.*)

Thickness and porosity of shell are important factors in market eggs because of their influence on breaking strength and maintenance of the quality of the yolk and white. Breaking strength depends largely on shell thickness. The keeping quality of the yolk and white depends largely on the thickness and porosity of the shell.

Shell thickness tends to decrease in hot weather. The number and size of pores in the shell are characteristic of each bird in the laying flock, although there is considerable variability among the eggs laid by each bird. Eggs that are highly porous tend to lose weight faster than other eggs, and thus deterioration of yolk and white proceeds at a more rapid rate.

Determining Quality by Candling. The only practicable method of determining the condition of the shell and yolk and white in the marketing of eggs is by passing light through them. Candling devices include gas, oil, electric, or gasoline lights, the one by far the most commonly used being electric. Candling, for the most part, is done in dark rooms, which should be kept thoroughly clean and well ventilated.

FIG. 199. Lower left insert, showing proper method of holding eggs when candling them. Main portion of picture shows how eggs are candled for grading and packing. (*U.S. Dept. Agr.*)

The contents of an egg are observed by placing it between the light of the "candle" and the eyes of the observer, with the egg about 1 ft. below and about 1 ft. in front of the eyes. The large end of the egg is placed before the aperture directly in front of the light, and the egg is given a quick twirl in order to cause the yolk and the white to rotate. A candle-light equivalent to from about 350 to 450 foot-candles is best. A relatively small aperture is better than a large one. The rotation of the egg enables the candler to observe the internal condition of the egg fairly well. In actual practice, an experienced egg candler holds 2 or occasionally 3 eggs in each hand, and with a twisting motion of the hand brings each egg in turn before the aperture, candling the eggs in both hands before picking up more eggs.

A supplementary method of candling has been developed in which "black" or ultraviolet light is used to detect relative freshness in eggs.

Fresh-laid brown and white eggs fluoresce scarlet, whereas after they are about 10 days old they fluoresce purple.

Shell. Candling reveals the condition of the shell as to whether it is sound or slightly or severely cracked. Any mottling of the shell is also observable, mottled areas being more translucent than the remainder of the shell. Mottling is due to an uneven distribution of moisture in the shell, nearly all of the mottling disappearing when the shell is dried. Eggs are sometimes observed that have "glassy" shells, which are not so porous as normal eggs.

Air Cell. Candling reveals the size of the air cell in an egg. At the time of laying no air cell is present, but appears within a short time after laying and is about the size of a dime or about ⅛ in. in depth, but in a warm temperature and dry atmosphere it increases in size. In candling market eggs, the depth of the air cell is used as a partial guide in determining the extent to which the yolk and white have deteriorated in quality. Eggs that have been handled very roughly may contain "tremulous" air cells, which means that the air cell is movable due to the separation of the inner and outer shell membranes beyond the margins of the normal air cell. Tremulous air cells have no relation to interior egg quality but merely indicate excessively rough handling of the eggs.

Yolk and White. Candling reveals to a considerable extent the quality of the yolk and white. The condition of the yolk and white are more readily discerned in white-shelled than in brown-shelled eggs; in white-shelled eggs the contents on candling appear pinkish yellow, whereas in brown-shelled eggs the contents appear reddish brown. In both kinds of eggs, the yolk appears as a diffused shadow as the egg is twirled before the candle. The distinctness of the shadow is influenced to some extent by the size of the egg, the yolk shadow being slightly more distinct in small than in large eggs.

Accompanying the whirling yolk shadow is usually seen an indistinct dark spot followed by a light spot, the dark spot being produced by the rotation of the outer end of the chalazas, and the light spot resulting from the reflection of light from the inside of the shell shining through the chalazas.

The outstanding differences between thick and thin white is that thin white contains practically no mucin, whereas thick white is rich in this protein substance. The transmission of light varies with the percentage of mucin contained in the thick white.

DETERIORATION IN QUALITY AND ITS CAUSES

The porous nature of the egg shell permits gases and water to escape from the egg and allows bacteria to enter the egg when eggs are exposed

to unsatisfactory environmental conditions. From the time that eggs are laid until the time they are consumed, they are often subjected to a variety of conditions which result in a marked deterioration in quality. The yolk and white are highly perishable, but the shell serves to conceal the deterioration that may have taken place as a result of improper conditions of handling and storing. Candling serves to detect defects in the shell, white, and yolk and enables the candler to estimate approximately the extent of deterioration in quality that has taken place in the white and yolk.

Loss in Egg Weight. When fresh-laid eggs are held in a warm room with a dry atmosphere, water passes from the albumen through the shell, and the air cell enlarges. Evaporation of water from the eggs proceeds steadily, the rate depending upon the temperature and the lack of humidity in the atmosphere of the room in which they are held. If eggs are held long enough under these unsatisfactory conditions, sufficient water may have been lost from the albumen so that the yolk tends to rise toward the shell and in some cases may become stuck to the inner shell membrane. The more porous the shell, the greater the speed of evaporation.

The increase in the size of the air cell is proportional to the loss of water from the egg. Air-cell size, as revealed by candling, is a better index of the condition under which eggs have been held than it is of the age of the egg. For instance, in fresh-laid eggs held for 10 days under satisfactory conditions with respect to humidity and temperature, the size of the air cell is much smaller than in eggs held for 3 or 4 days in a very warm room having a very dry atmosphere.

Liquefaction. When eggs are held in too high a temperature, there is a general breaking down of the albumen, a weakening of the vitelline membrane surrounding the yolk, and increased flaccidity of the yolk. During the early holding period, water from the albumen not only evaporates through the shell but also passes through the vitelline membrane to the yolk because the osmotic pressure of the yolk is greater than that of the albumen. The enlargement of the yolk tends to stretch and weaken the vitelline membrane so that when the contents of the egg are broken out, the yolk lies relatively flattened.

As eggs deteriorate in quality, the thick white tends to break down into thin white and the yolk becomes more mobile, causing a more distinct yolk shadow when the egg is twirled before the candle. The deterioration of the thick white results to some extent from the disappearance of the mucin fibers, their disappearance apparently being due to the increased alkalinity of the thick white. Thus, under the influence of relatively high temperatures, the albumen of the egg becomes "watery."

Bacterial Decomposition. Fresh-laid eggs that are perfectly clean are normally free of bacteria both with respect to the shell and the contents. So long as the shells are kept dry and clean, bacterial decomposition of the contents should not be a problem either in fresh-laid, held, or stored eggs.

The mucinous material of the cuticle of the shell tends to prevent bacteria from penetrating the shell. The shell membranes have a certain degree of bactericidal activity which enables them to destroy bacteria before they enter the albumen. Also, the albumen in fresh-laid eggs has bactericidal properties that tend to prevent bacteria from gaining access to the yolk, and the alkalinity of held eggs is unfavorable to the growth of bacteria.

On the other hand, eggs stained with fecal matter or with contaminated soil may result in bacterial decomposition, especially if the shells become moistened. In addition, a certain percentage of the shells of eggs produced on nearly every farm and commercial-poultry plant become slightly or severely cracked while being gathered, graded, and packed for market. Such eggs are quite susceptible to bacterial invasion.

Green Rots or Sour Eggs. In these eggs, the albumen has undergone a certain degree of liquefaction, may be stringy, and usually appears green in color. The yolk may be covered with pink-and-white specks and often resembles a partially cooked yolk. The vitelline membrane may be thickened and white or sometimes black. Green rots are usually caused by members of the genus Pseudomonas, which is a widespread soil microorganism. Infected eggs are difficult to detect by candling, especially in the early stages. In later stages of deterioration, the stringiness of the albumen can be detected in the small end of the egg, and the yolk shadow often appears dark and reddish in color. It has been definitely established that the bacteria enter the egg only after it is laid and that penetration is accelerated when the shells of eggs are stained with contaminated material while the eggs are warm. The effects of bacterial contamination are not detectable until the eggs have been stored for a considerable period. Therefore, all stained eggs should not be packed for storage, even after having been cleaned.

Red Rots. Bacteria of the Pseudomonas group give rise to a distinct reddish tinge in the yolk, which can be detected by candling. The albumen is usually liquefied and has a grayish cast containing reddish-colored patches.

Black Rots. The characteristic features of these eggs when candled are large, movable air cells filled with gas, greenish-brown watery whites, and black yolks. When opened, the eggs emit a foul odor, and the yolks appear rubbery. The bacteria most frequently found to be present

belong to the Alcaligenes, Escherichia, and Proteus groups, all of which are present in the soil and fecal material. Dirt on the shell and contaminated water used in washing eggs are the most common sources of infection. Black rots may occur in eggs shortly after being laid.

Deterioration Resulting from Fertility. In this case, a "heat spot" appears as a reddened spot on the surface of the yolk of a fertile egg and is due to early embryo development which is later arrested. An egg with a "blood ring" is the result of the development of the embryo for a few days, after which death occurs, leaving the blood of the embryo in a small ring.

Blood Spots and Clots and Bloody Eggs. Blood spots and clots have the same origin and differ only in size. They originate, for the most part, between the follicle and vitelline membrane while the yolk is in the ovary. Bloody eggs are those in which the albumen is reddened with blood. These eggs have been discussed in the chapter on The Biology of the Chicken.

Albumen Defects Caused by Disease. Birds infected with the virus which causes Newcastle disease often lay eggs containing no true air cells but, instead, several small, free-floating air bubbles, and the albumen quality is lowered. "Pinkish whites" may result from hens having access to certain weeds and other products, previously discussed in the chapter on Feeding Practice.

Discolored Yolks. The yolk tends to become darker in color as the air cell increases in size and as the egg increases in age. The density of the yolk shadow when an egg is candled is determined not only by the color of the yolk but by the extent to which the thick white has liquefied. Shaking a fresh-laid egg tends to deepen the yolk shadow. A "mottled-yolk" condition is sometimes due to the imperfect condition of the peripheral layer of light yolk, allowing areas of dark yolk lying beneath to show through. Mottled yolks, olive-colored yolks, and other yolk discolorations due to diet have been discussed previously in the chapter on Feeding Practice.

Odors and Flavors. The porous nature of the shell allows the egg to absorb odors and flavors quite readily. Eggs laid in nests recently disinfected with creosote are liable to acquire a tainted flavor. Eggs having objectionable odors are sometimes laid by hens fed grain that has been treated with formalin and by hens on range that have eaten rape, garlic, or large numbers of army worms. Laying eggs with a "fishy" flavor seems to be a characteristic of a few birds in certain flocks, these offenders also having a "fishy" breath. Eggs stored or packed in musty cartons or flats and fillers acquire a musty odor. Eggs should not be allowed to come in contact with onions, kerosene, or other objects with strong odors.

Defective Shells. An egg with a crack in the shell so small that it can only be detected by candling or by tapping the egg against one with a sound shell is known as a "blind check." An egg in which the shell has apparently been cracked in the uterus of the oviduct and then more shell material was deposited over the crack is known as a "body check."

Foreign Substances in Eggs. Very occasionally an egg may be encountered containing a foreign substance which entered the posterior end of the oviduct.

PRESERVING EGG QUALITY

The importance of preserving the superior quality of fresh-laid eggs cannot be overemphasized, because the quality of market eggs affects their price, the number consumed, and the costs of marketing. The

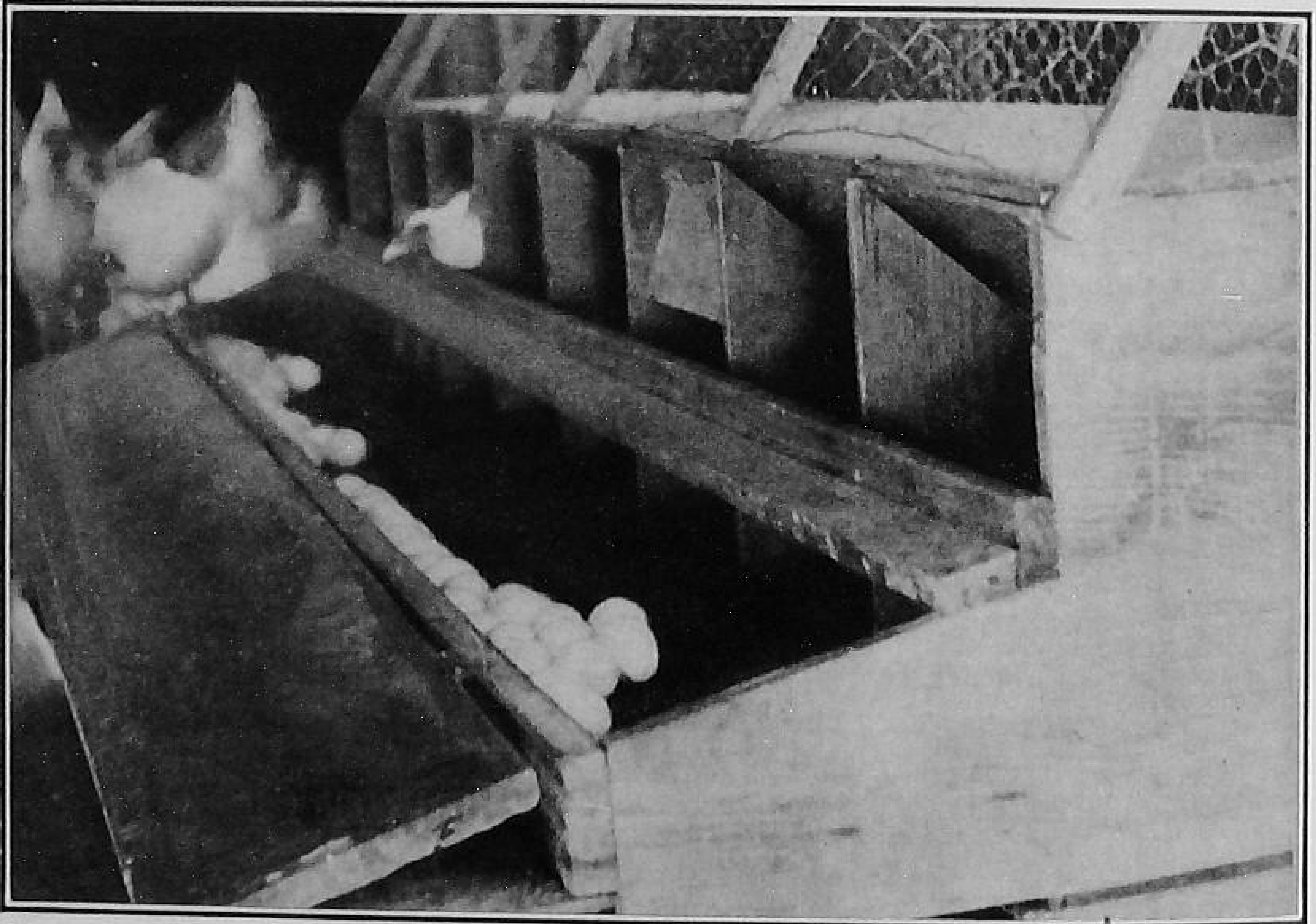

Fig. 200. Type of nest used by W. E. Stahl in California to keep eggs clean. The door over the section of the nest where the eggs roll forward on the slightly slanted wire-nest bottom is opened to permit gathering the eggs. (*Nulaid News.*)

marketing of bad eggs means loss in shipping costs and a lower average price for all eggs marketed. The greater the care given in preserving the quality of eggs on the farm, the less the expense involved in relation to their value in maintaining their quality while they are passing through the various channels of distribution and the greater the consumption. Stale eggs kill the demand for eggs more than high prices do.

From what has been said previously in the section on causes of deterio-

ration in egg quality, it is apparent that a reasonably low temperature is the first requisite in the preservation of egg quality. Other factors of outstanding importance include the humidity of the atmosphere in which eggs are held, the cleanliness of eggshells and all utensils and equipment used in handling and packing eggs, conditions of handling and storing, and the time that elapses between the production and consumption of the eggs.

Producer Preservation of Egg Quality. In order to be able to market the highest percentage of eggs possessing the superior quality that is characteristic of fresh-laid eggs, producers should produce infertile clean eggs.

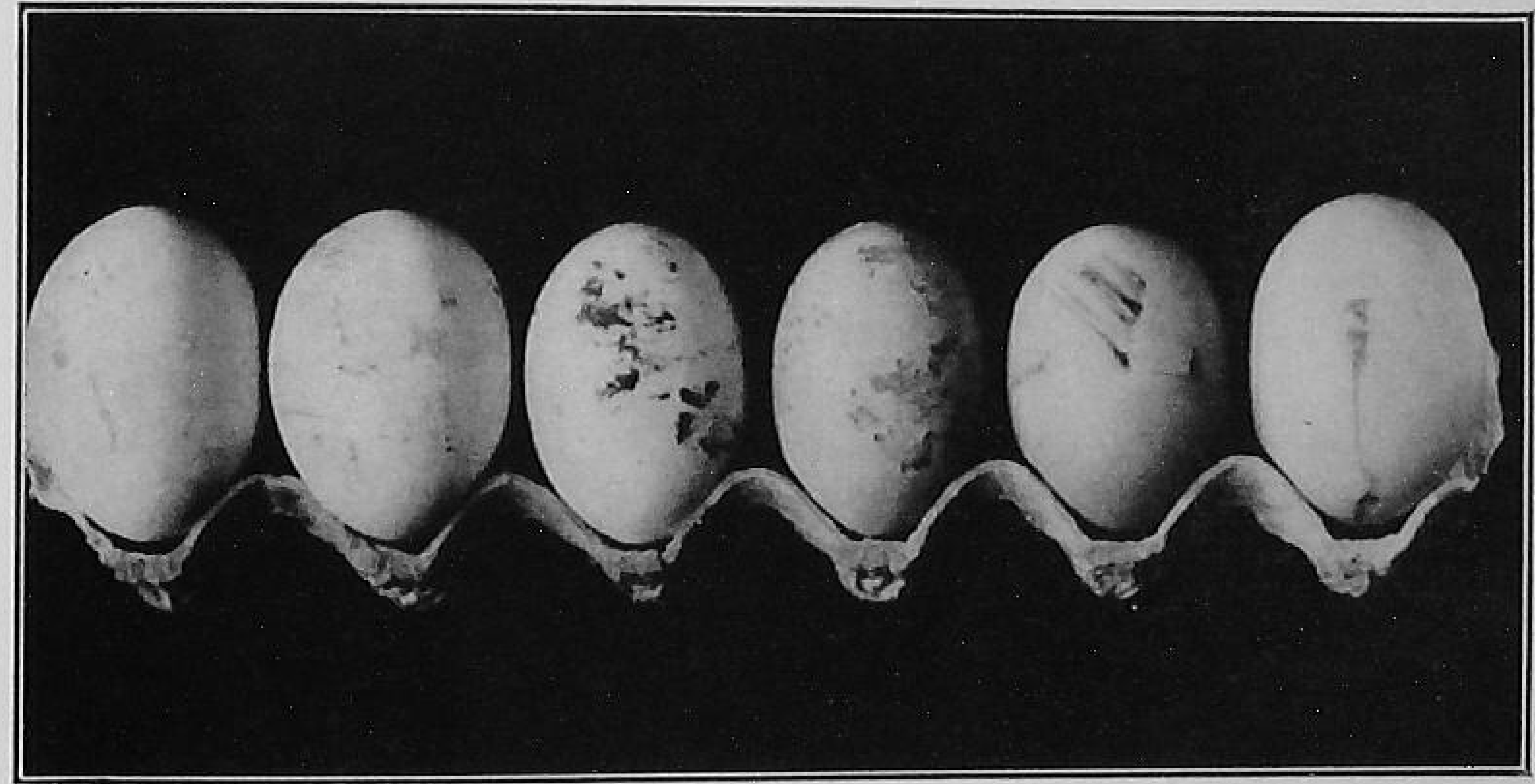

FIG. 201. Soiled eggs should be cleaned, but washed eggs, for the most part, should be marketed immediately. (*E. S. Snyder, Ontario Agr. Coll.*)

Fertile market eggs that are not cooled promptly and kept relatively cool often give rise to the development of heat spots, blood rings, dead germs, and one or more kinds of rots. Broody hens should not be allowed to remain on the nests. Infertile eggs rarely develop into rots. Hatchery-flock owners should remove the males from the breeding flocks as soon as the breeding season is over.

Producing clean eggs reduces the possibility of bacterial decomposition. When an egg becomes soiled, it usually becomes moistened at the same time, and thus the bacteria in the feces or soil on the shell are able to enter the egg through the pores of the moistened shell. In order to keep the production of dirty eggs at a minimum, the laying-house litter should be kept reasonably dry and the nests should be provided with clean nesting material at all times. There should be plenty of nests, approximately one for every four birds, or better still, tunnel nests should be used, in order to keep egg breakage at a minimum. The droppings boards or

droppings pits should be covered with wire screens to prevent the birds from tracking feces to the nests. Some poultrymen sprinkle gypsum on the lighting board in front of the nests in order to reduce soiling the eggs by hens' dirty feet. Wire-bottom nests are used by some poultrymen. If the poultry yard is bare and muddy, it is well to keep the hens confined until midafternoon because most of the eggs for that day will have been laid. Gathering eggs at frequent intervals every day tends to reduce the number of dirty eggs.

Washing Dirty Eggs. On many farms and commercial-poultry plants, washing dirty eggs is a serious problem because of the time and labor

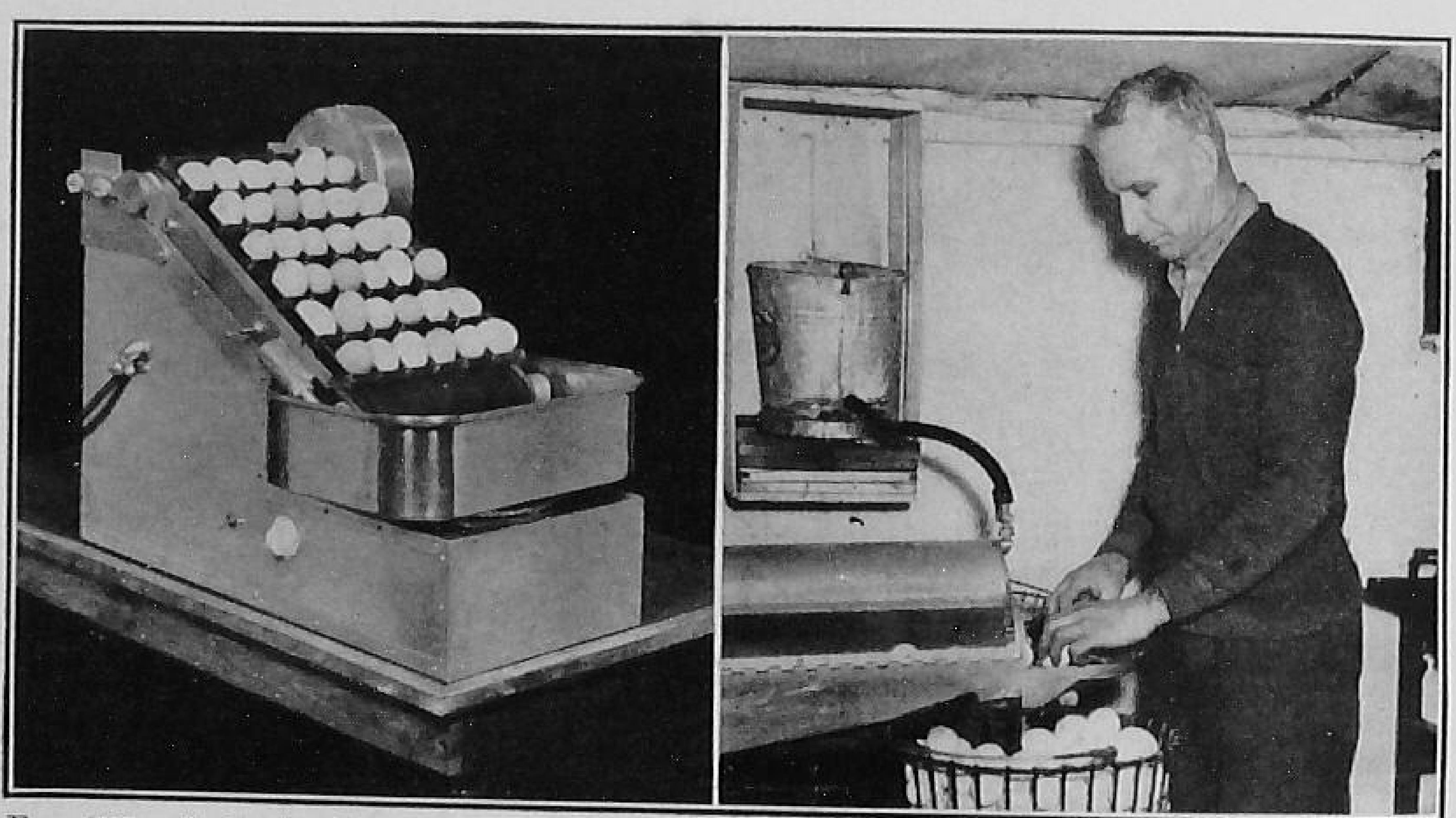

FIG. 202. Left, the Gwin mechanical egg washer. (*Douglas, Brown, and Campbell, Ltd.*) Right, the G.L.F. mechanical egg washer. (*F. B. Wright.*)

required. At the same time, dirty eggs, including those improperly cleaned, are responsible for the loss of millions of dollars every year.

For many years the commonly recommended method of cleaning dirty eggs has been dry cleaning with steel wool, emery paper, or sandpaper. In many respects dry cleaning is preferable to washing but requires more time and frequently the shells are scratched, especially in the case of brown eggs.

Dirty eggs for immediate sale may be washed, but the water used should be clean and at all times warmer than the eggs. A temperature of about 160°F. is recommended. If cold water is used, bacteria may enter the egg through the opened pores. Dirty eggs should be washed the day they are gathered. Some poultrymen have made a practice of dipping each day's collection of eggs contained in wire baskets in a detergent solution to clean the dirty ones, but this is unwise because washing

clean eggs may be detrimental to maintenance of quality while eggs are in transit to market or if they are to be stored.

Sodium hydroxide used in the washing water helps to prevent bacterial decomposition within the egg. The washing water should contain 0.35 per cent sodium hydroxide, and rubber gloves should be worn to protect the hands. Whether plain water or water to which a chemical has been added is used for washing eggs, dirty eggs should be washed as soon as possible after they are gathered. The eggs should not be allowed to remain in the water for any length of time, and the water should be

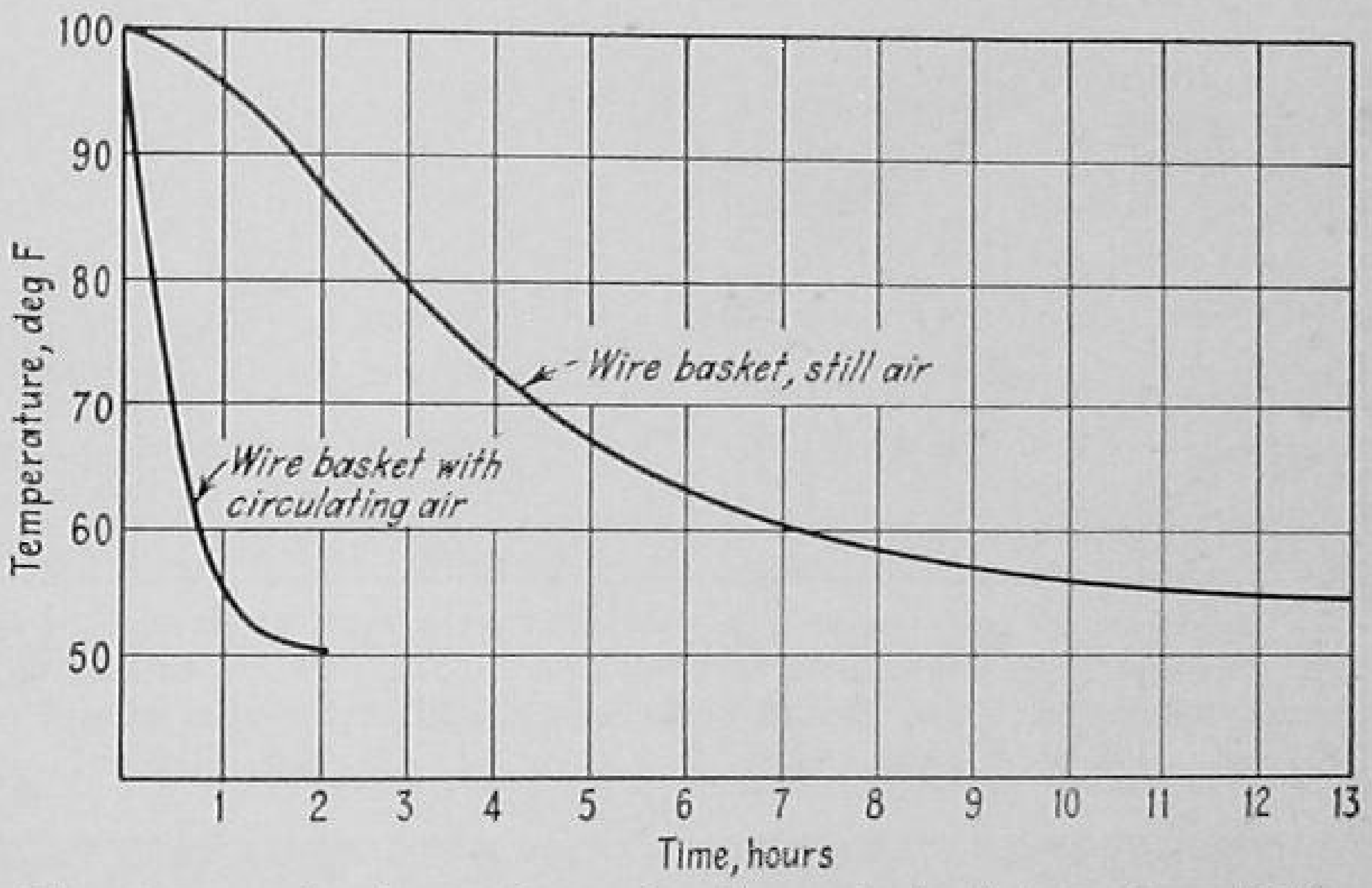

FIG. 203. The time required to cool eggs, kept in a wire basket, to about 55°F. was about 1 hr. when the air was kept in circulation as compared with about 12 hr. in still air. (*E. M. Funk, Mo. Agr. Exp. Sta.*)

changed frequently to avoid contamination. The washed eggs should be dried promptly. Washing dirty hatching eggs apparently does not affect hatchability.

Satisfactory Holding Conditions. During warm weather, market eggs should be gathered frequently every day and taken from the laying house to a satisfactory egg-holding room. The eggs should be collected in wire baskets in order that cooling may proceed rapidly. Cooling takes place most rapidly if the eggs are promptly removed from the wire baskets and placed on wire-bottom trays, an electric fan to circulate the air in the egg room accelerating the rate of cooling. If the volume of eggs produced daily is too large to be placed on wire-bottom trays, they should be cooled as promptly as possible in the baskets in which they were collected.

The temperature of the egg room should be about 50°F., and the relative humidity should be about 70 per cent. Microscopic germ development does not take place in fertile eggs to any material extent when they

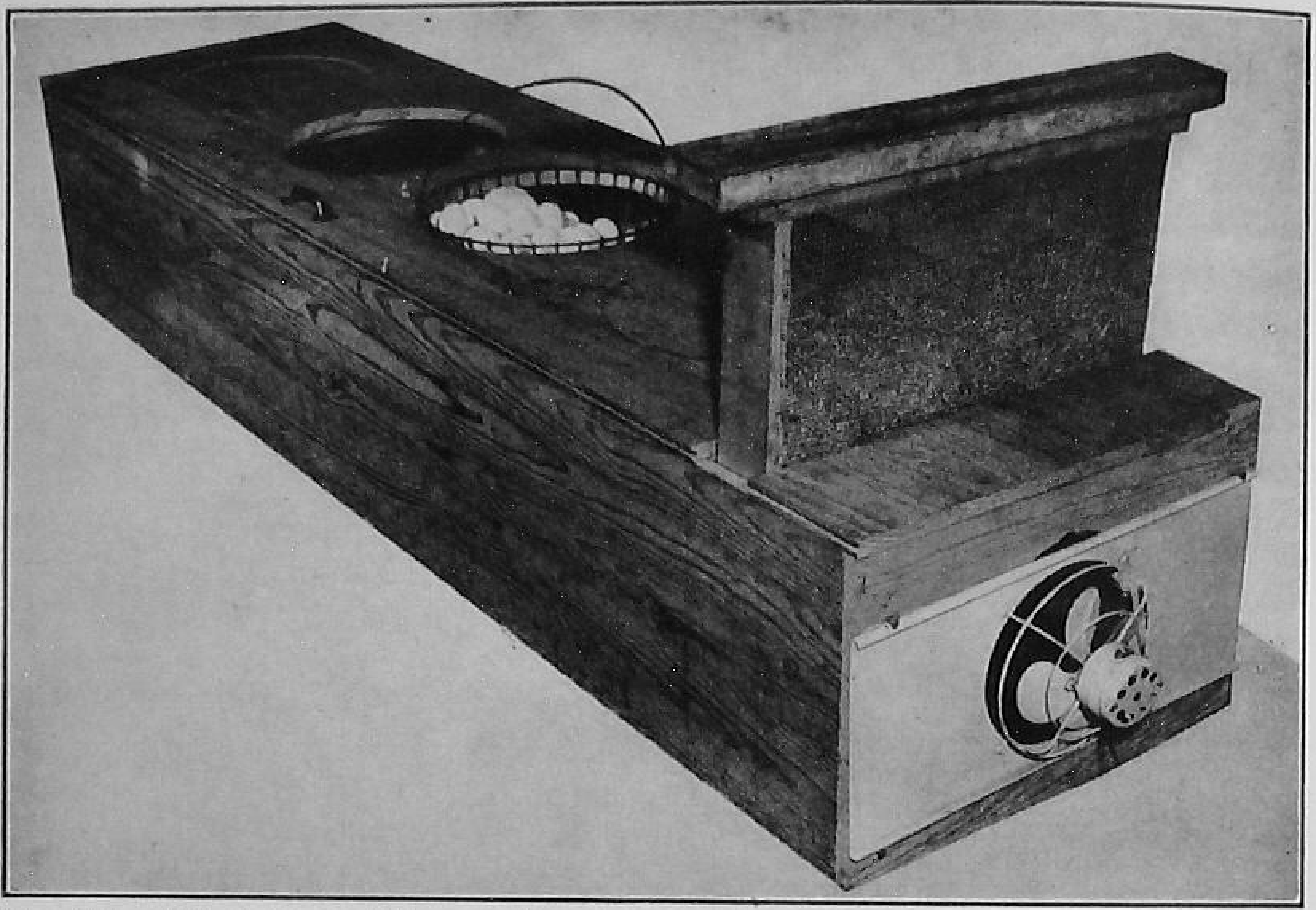

Fig. 204. A "wind-tunnel" egg cooler, air being blown through water-soaked excelsior or other material and then over the eggs in wire baskets. After about 1 hr. the eggs may be packed in cooled egg cases, which should be kept in a cool, relatively humid place until shipped to market. (*E. R. Winner and N. R. Clizer, Mo. Agr. Ext. Service.*)

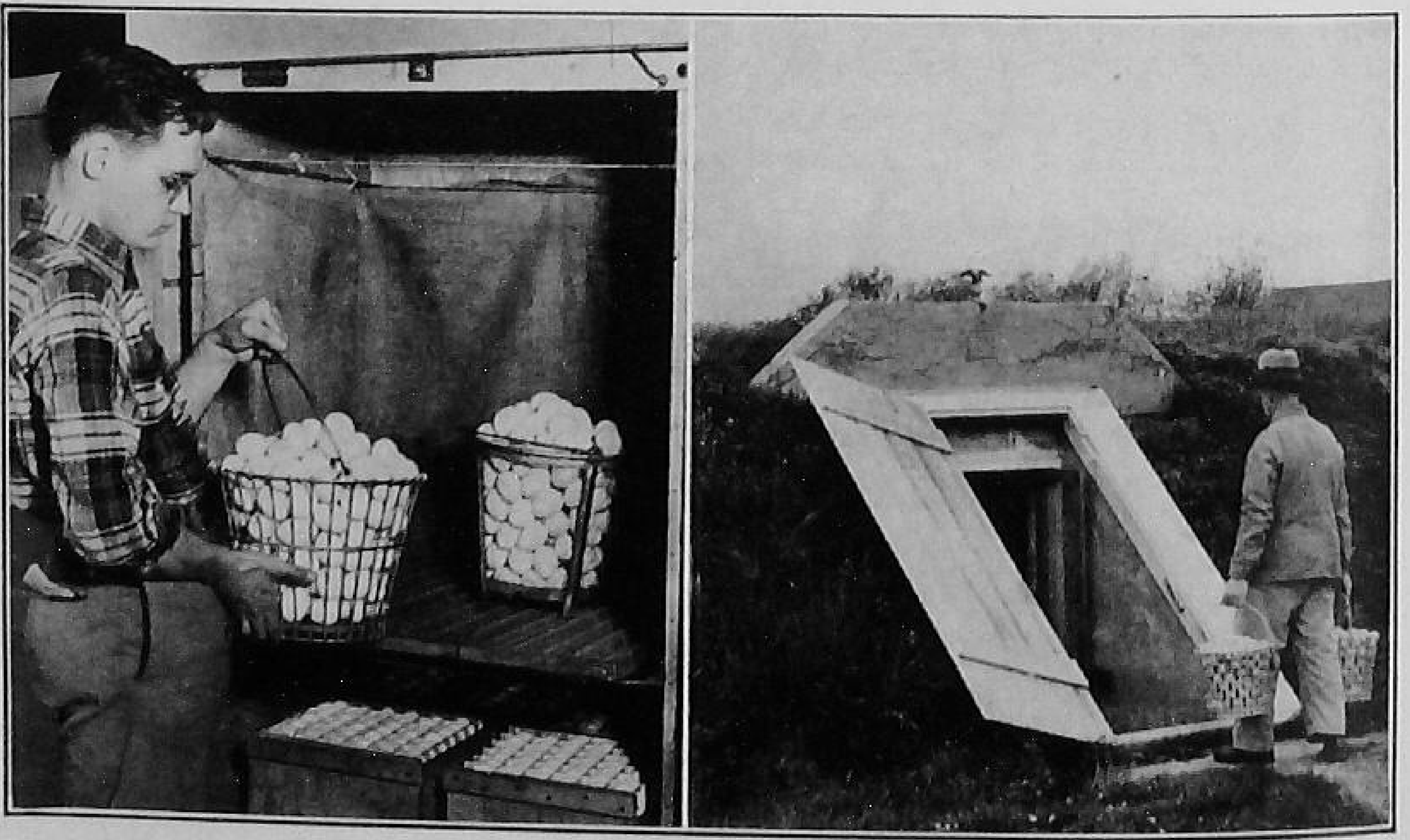

Fig. 205. Left, a cool, humid egg room tends to maintain high quality. This room is located in the basement: note the wet burlap to maintain relatively high humidity. (*P. Moore, C. E. Lampman, and H. Beresford, University of Idaho.*) Right, an egg cellar covered with earth and growing grass. Two terra-cotta pipes through the roof provide ventilation. (*C. O. Dossin and F. H. Leuschner, Pa. Agr. Ext. Service.*)

are held at temperatures below 80°F., but at 85°F. germ development proceeds quite rapidly. Holding eggs at about 50°F. is recommended, however, to best ensure the preservation of the fresh-laid quality of the white and yolk.

A well-ventilated room is very desirable. If the room is normally dry, water may be sprinkled on the floor or wet burlap sacks may be hung on the sides of the room. If mildew tends to develop on the burlap, it may be dipped in a dilute solution of copper sulfate, 1/8 lb. per gal. of water. Circulating air in the egg room speeds up the cooling of the eggs, but the humidity should be kept relatively high or the eggs may lose weight. The cartons, cases, flats, and fillers should be thoroughly chilled before eggs are packed in them.

Preserving Eggs for Home Use. The home preservation of eggs has been practiced for many years. When prices are low in the spring, it is frequently advantageous to preserve a few eggs for cooking and baking purposes during the fall and winter months. Only fresh eggs of the very best possible quality should be used, and they should be clean and sound in shell. The room in which the eggs are stored should be kept at 40°F. or lower.

The eggs are preserved in a solution of water glass (soluble sodium silicate). To 9 parts boiled rain water that has been cooled, add 1 part water glass. Put the solution in a crock, or glass container, that can be kept sealed to prevent evaporation, and place the eggs in it as they are gathered every day. Place them with the large end uppermost, and be sure that there is at least 2 in. of the solution above the top layer of eggs. The eggs may be kept in the solution for several months. If they are to be cooked, pierce the air cell with a needle before cooking to prevent them from cracking during the cooking process.

Another method of preserving the fresh-laid quality of eggs for use in the home for about a month is to dip them for 5 sec. in boiling water and, after they have been cooled at room temperature, keep them in the refrigerator until they are to be used. This process coagulates a very thin layer of albumen next to the inner shell membrane, thus protecting the balance of the white and the yolk from further rapid deterioration in quality.

Dealer Control of Egg Quality. The efforts of producers in preserving egg quality may be largely wasted, except in the case of those eggs sold direct to their customers, if dealers who buy and sell eggs do not do everything possible to provide consumers with eggs of the highest possible quality. During the warmer seasons of the year it is particularly important that trucks used for hauling eggs should be equipped with cooling facilities. Cases of eggs should never be exposed to the direct rays of

the sun any longer than is absolutely necessary. In stores where eggs are sold direct to consumers, the cartons of eggs should be kept in the refrigerator or in a show case that is kept at a low temperature.

Preserving Quality in Storage. Producers in all parts of the country should appreciate the function that the cold storage of eggs serves in regulating prices in such a way as to increase production returns. Up to a few years ago over one-half of the total annual egg crop in the United States was produced in the 4 months of March, April, May, and June. This uneven seasonal production results in a surplus of eggs during the spring and early summer seasons and a corresponding scarcity during the fall and winter months. On the other hand, the consumption of eggs is fairly stable throughout the year, except that in the spring months it is greater but is still not enough to take up the surplus produced during that time.

Although for many years past it was customary to hold eggs in storage for approximately 7 or 8 months, the tendency now is for the storage period to be shortened to about 4 or 5 months. This change is largely the result of relatively heavier egg production during January and February in recent years as compared with several years ago. Many cold-storage operators have found it highly advantageous to dispose of their storage holdings during the late summer and early fall months.

The surplus eggs are packed in 30-doz. egg cases, with new fillers and flats, placed in cold storage, and then taken out again to make up the shortage in egg supply during the fall and winter months. The placing of eggs in cold storage and holding them there to put on the markets when there is a shortage tends to stabilize prices. At the same time it is estimated that approximately only about 10 to 15 per cent of the total annual production of eggs is placed in storage each year. The proper storage of these eggs with a view toward preserving their quality is of great importance, because their quality when taken out of storage influences the general price level of all other eggs.

Since it has been shown that for different lots of eggs, kept under similar conditions of storage, the quality of the eggs, upon being taken out of storage, is in direct relation to their quality when placed in storage, it is obvious that the greatest possible care should be exercised in the selection of only the best possible quality of eggs for storage purposes.

Much research has been undertaken to determine the proper conditions of temperature, humidity, and ventilation necessary for preserving egg quality. The temperature of storage rooms should be held at 29 to about 30°F., but each storage room must be tested separately to determine the proper humidity and ventilation to be maintained.

A high relative humidity in the storage room is desirable in order to

prevent excessive evaporation of water from the eggs, but mold grows luxuriantly if the relative humidity at the shell surface is 96 per cent or higher. At relative humidities ranging from 90 to 94 per cent a slight white mold called "whiskers" occurs, many storage operators using this phenomenon as an indication that a desirable relative humidity is being maintained. It is desirable to provide automatic ventilation of the air in storage rooms in order to control mold growth. The rate of air circulation should not be excessive, and there should be free circulation of air around the cases, but the ventilating fan should not blow directly against the cases. The bottom layers of cases should be placed on slatted racks about 4 in. above the floor, and thin slats should be used between the layers of cases.

It has been shown that when the air of the storage room contains 1 per cent carbon dioxide, deterioration in egg quality is retarded, especially with respect to the breakdown of mucin in the thick white. The element of danger to humans should always be kept in mind when CO_2 is added to the air of storage rooms, even at the 1 per cent level. Ozone added to the air of storage rooms at the level of 1.5 parts per million helps to control mold growth on the shells and is an effective deodorant but is corrosive to rubber fittings around the doors of cold-storage rooms.

Shell Sealing to Preserve Egg Quality. Several years ago it was found that the keeping quality of eggs held in storage for a few months was enhanced considerably if the eggs were dipped in oil prior to being placed in storage. Subsequently, it was also found that the same was true for eggs not placed in cold storage. Enormous numbers of eggs are oil treated every year by egg dealers and to some extent by egg producers. Naturally the bulk of the eggs that are dipped in oil are produced in the spring months, although year-round dipping is practiced to some extent in certain sections of the country.

Coating the shells with oil seals the pores and tends to prevent the evaporation of water and the escape of carbon dioxide from the egg. Thus, the hydrogen-ion concentration (alkalinity) of the albumen increases less rapidly in shell-treated eggs than in eggs that are not shell treated.

The oil used is a colorless, odorless, and tasteless mineral oil of such viscosity as to cover the shell thoroughly and of such persistency as to reduce the loss of water and carbon dioxide from the egg to the greatest possible extent, the persistency of the oil being determined by its rate of evaporation. Pentane-mineral oils are very efficient in preventing the loss of interior quality, as little as from 1 to 2 per cent being effective in preventing the deterioration of thick white. Shells so treated have practically no shiny appearance. Carbon tetrachloride gives practically

the same result. Pentachlorophenol tends to inhibit mold growth during the storage period. The temperature of the oil is usually kept at 70°F., although in former years oil at 160°F. was used extensively. It is important that the temperature of oil should be a few degrees higher than the temperature of the eggs to be oiled.

The results of recent experiments have shown that quite a wide range of time and temperature treatments with mineral oil may be employed

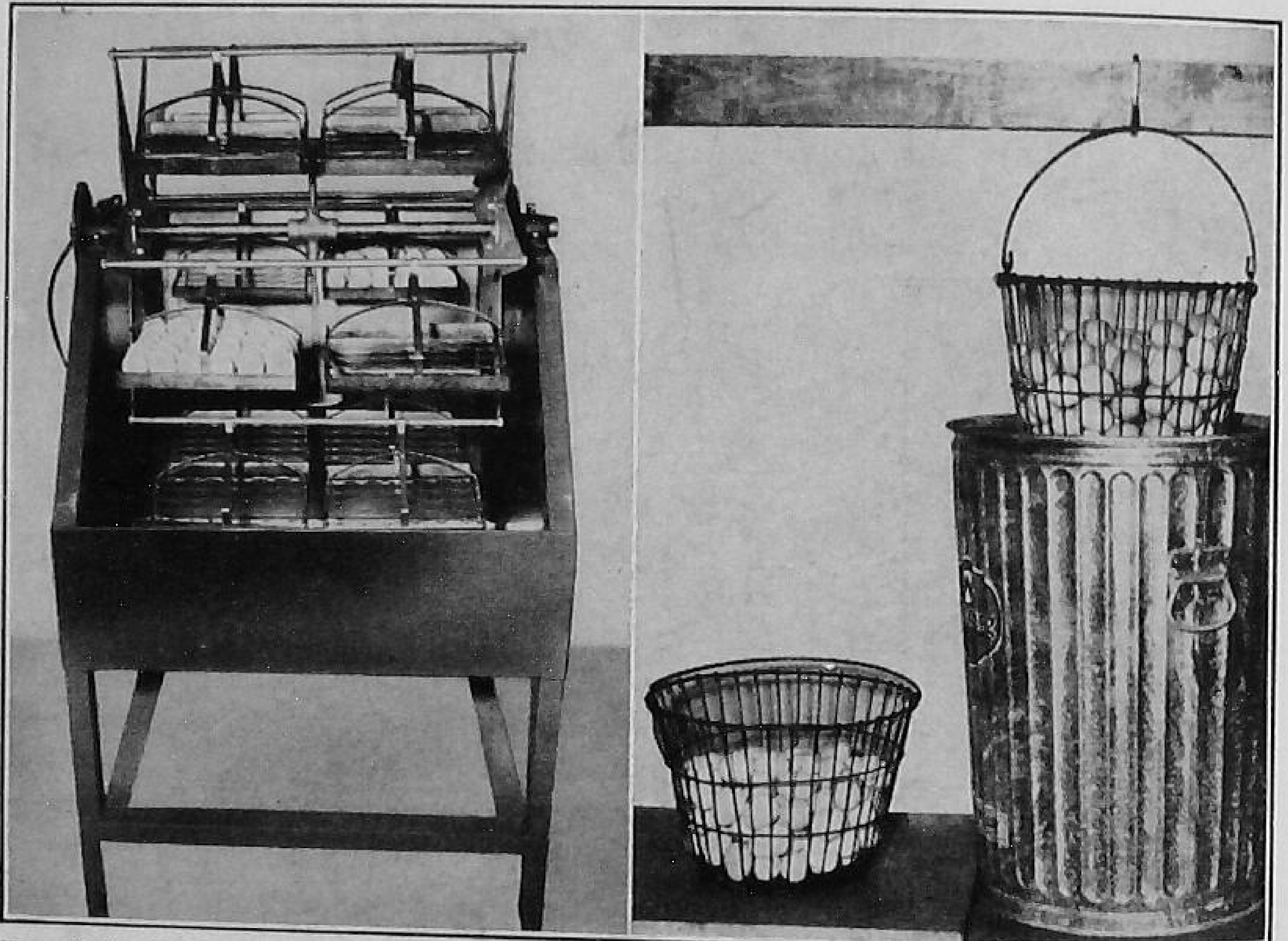

FIG. 206. Left, an oil-dipping machine frequently used in egg-packing plants. The eggs on trays, each holding 3 doz., are automatically dipped and lifted for draining. Right, a simple arrangement for oil-dipping eggs on producers' premises includes a large galvanized ash can and wire baskets in which eggs are collected. (*A. R. Winter and O. J. Cotterill, Ohio State University.*)

with day-old eggs and still give apparently comparable results in interior egg quality after from 4 to 7 months of storage. Examples of satisfactory treatments were as follows: 80°F. for 20 sec.; 100°F. for 80 sec.; 120°F. for 20 sec.; 140°F. for 40 sec.; 160°F. for 10 sec.; 180°F. for 10 sec.

The keeping quality of shell-treated eggs is influenced greatly by the degree of sanitation practiced in the process of oiling. The use of contaminated oil gives rise to mold growth. Either new oil only should be used every day or what is left from the previous day's operation should be filtered and sterilized at 180°F. for 20 min. When large numbers of eggs are being oiled every day, it is well to change the oil at noon to avoid excessive contamination of the oil.

Only high-quality eggs are shell treated; and immediately after being laid, they should be cooled in a 50°F. holding room for about 18 hr. so that the internal temperature of the eggs is reduced to between 50 and 60°F. In warm weather, eggs that are not cooled promptly after being laid and before being dipped in oil may develop a pink-white condition during the storage period. The shells of eggs to be dipped in oil should be thoroughly dry. For this reason, eggs should not be held at too low a temperature before being oiled, otherwise, when taken out of the holding room, moisture condenses on the shell. Eggs that have been oiled prop-

Fig. 207. Breaking eggs, the first step in preparing frozen and dried eggs. (*Ovson Egg Company, courtesy of Processing Equipment News.*)

erly will not stain the flats or fillers when the eggs are packed in cases for storage. Immediately after being oiled, the eggs should be chilled in order to maintain interior quality.

Thermostabilizing to Preserve Egg Quality. If eggs are dipped in hot water or hot oil at a sufficiently high temperature for a sufficient length of time, deterioration of egg quality tends to be retarded when such eggs are stored. This method of treatment destroys life in blastoderms of fertile eggs. Also, numerous species of bacteria that may be on the shells of eggs and in the pores of the shells are destroyed, because of which the process is often referred to as the "pasteurization" of shell eggs. In one experiment it was found that thermostabilizing day-old eggs for 15 min.

at 140°F. resulted in their maintaining good interior quality for as long as 7 months in storage. In some cases, however, it has been found that yolks become stuck to the shells. Thermostabilizing makes candling more difficult, so that experience is necessary to grade thermostabilized eggs properly.

Freezing Yolks and Whites. The freezing of yolks and whites is a method of preserving their quality, the frozen product being used in the baking industry and for making candy, ice cream, mayonnaise, and other food products. For the most part, the freezing of yolks and whites is carried on during the season from March to September, eggs being most abundant and relatively cheap from March through May. This benefits the producer, otherwise the price of shell eggs would be still lower if considerable quantities were not broken out to preserve their quality for later use. Also, frozen yolks and whites occupy much less space in storage and are more convenient for large-scale use than eggs in the shell. Most of the frozen-egg products are prepared in the Middle West and Texas.

Drying Yolks and Whites. Removing most of the moisture from yolks and whites and packing the dried products in tins is another way of conserving egg quality. The removal of water tends to decrease bacterial growth, and much space is saved in storing. Eggs laid in the spring produce a relatively better dried-egg product than those laid during other seasons of the year. Liquid mixed yolks and whites and liquid yolks are dried by the spray method and liquid whites by the pan method. Dried eggs may be served on consumers' tables, and dried yolks and whites as well as dried whole eggs are used in baking various products and in other ways.

GRADING EGGS IN THE SHELL

It has been shown previously that all eggs as they are sold by producers are not of the same quality, but even if they were they would show differences before they reached the consumer. Differences in methods of handling eggs and different lengths of time for various lots of eggs to reach the various markets produce changes in their quality. The particular grade into which a particular lot of eggs is classified depends in a large measure upon the extent to which their original quality has been preserved.

The establishment of grades of eggs is based upon differences that exist with respect to their exterior and interior quality. The different characteristics determining exterior quality that are taken into consideration in grading eggs include (1) cleanliness of shell, (2) soundness of shell, (3) size, (4) color, and (5) shape. The different characteristics deter-

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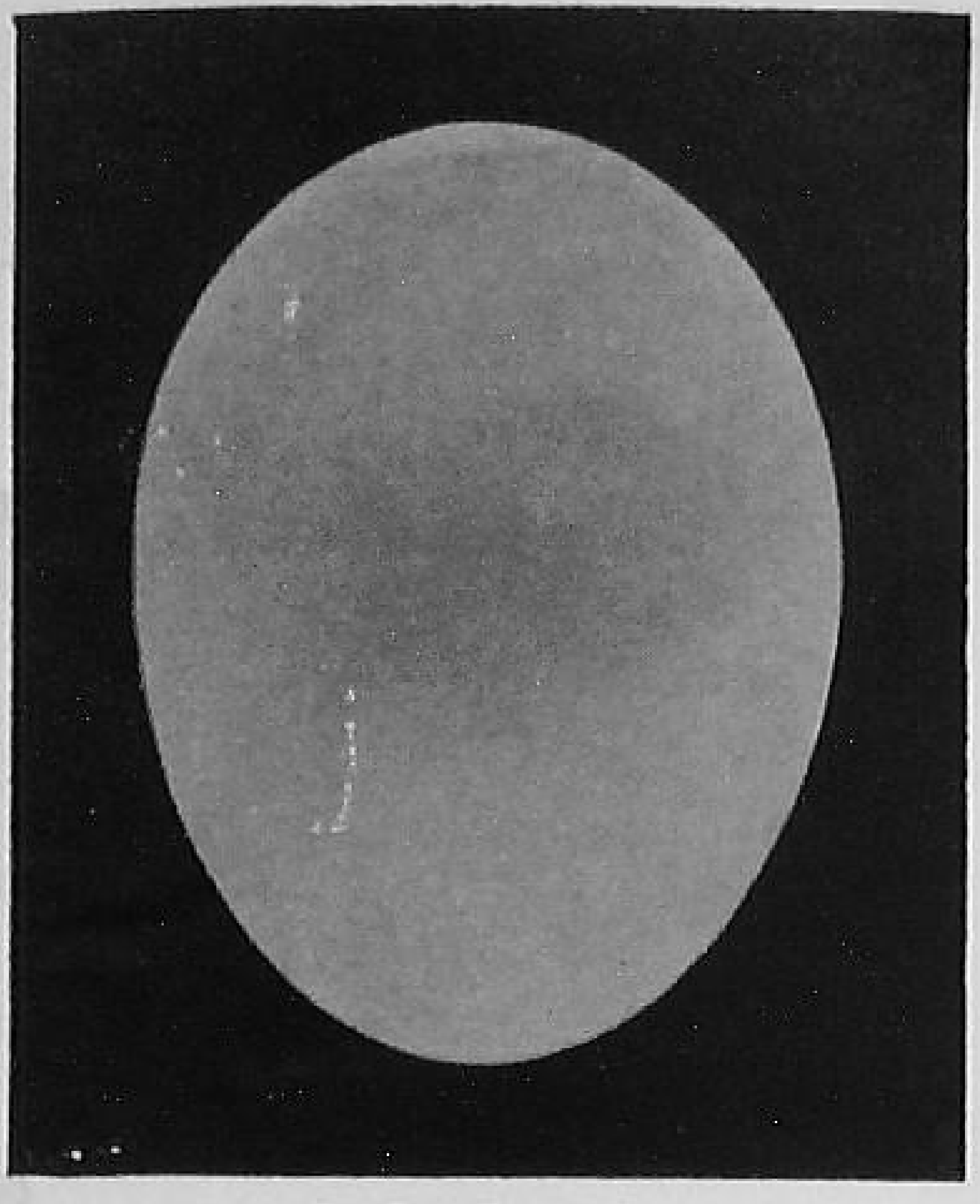
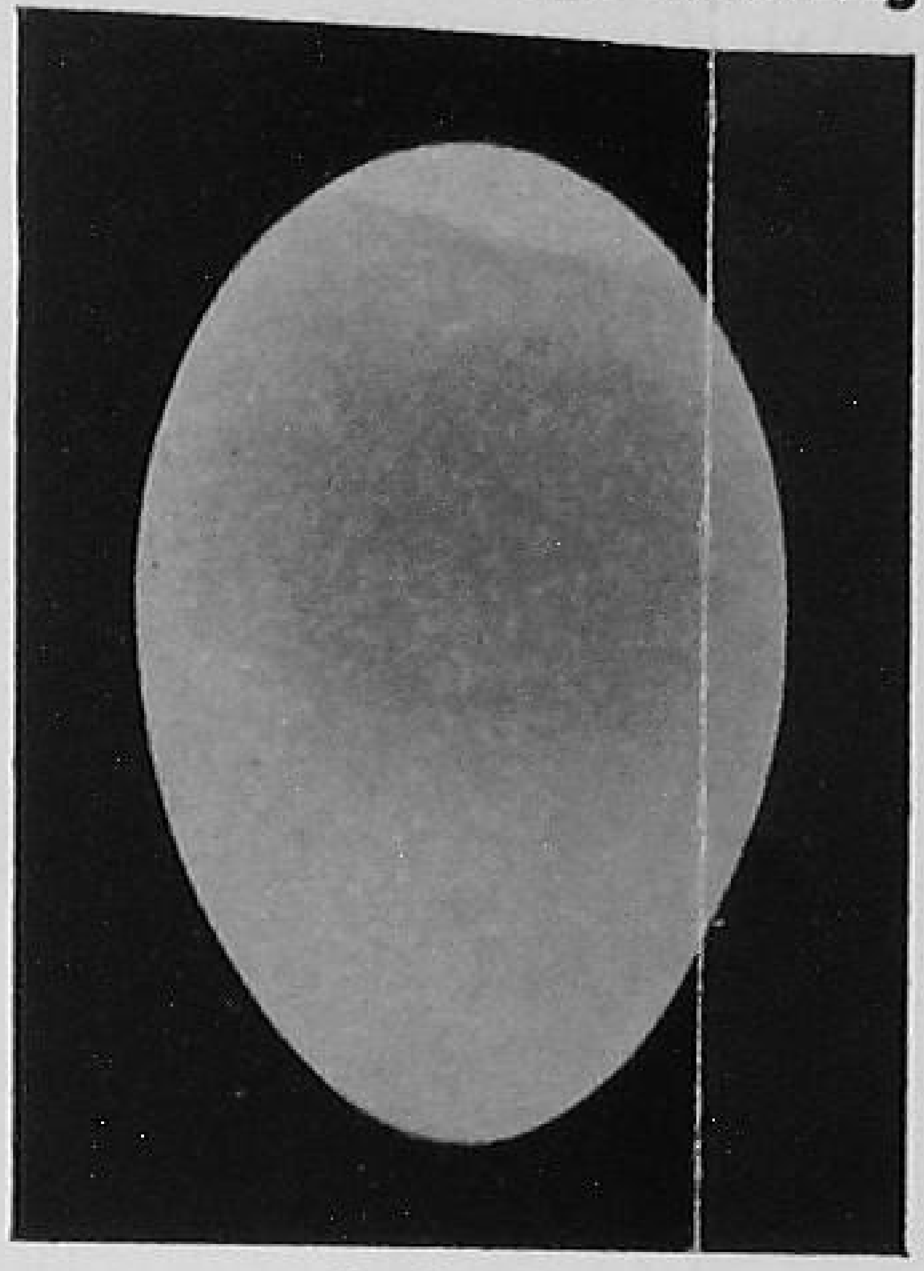
Illustrations of candled appearance of white-shelled eggs showing maximum depth of air cell and outline



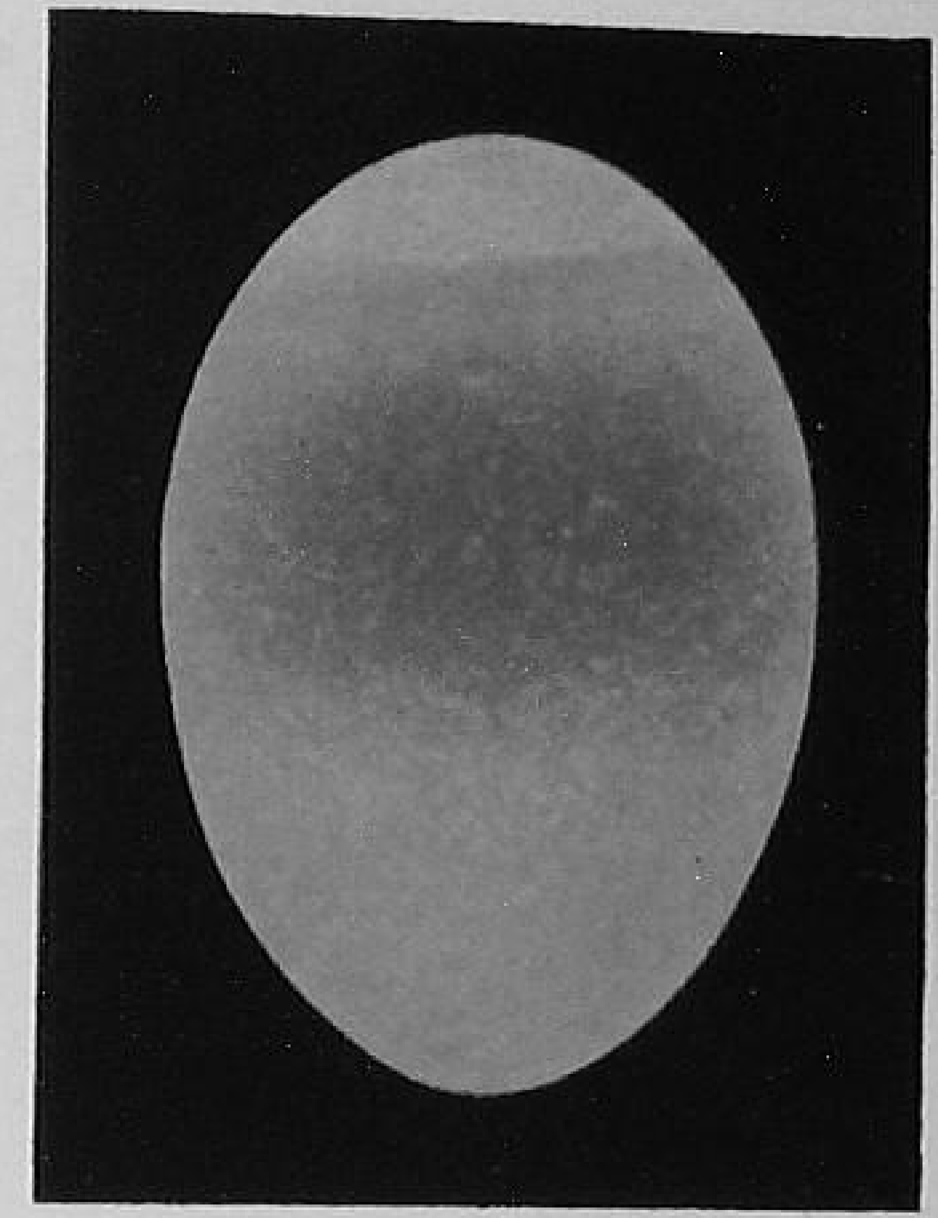
AA Quality

1. Shell—clean; unbroken; practically normal.
2. Air cell—1/8 inch or less in depth; practically regular.
3. White—clear; firm.
4. Yolk—well centered; outline slightly defined; free from defects.



A Quality

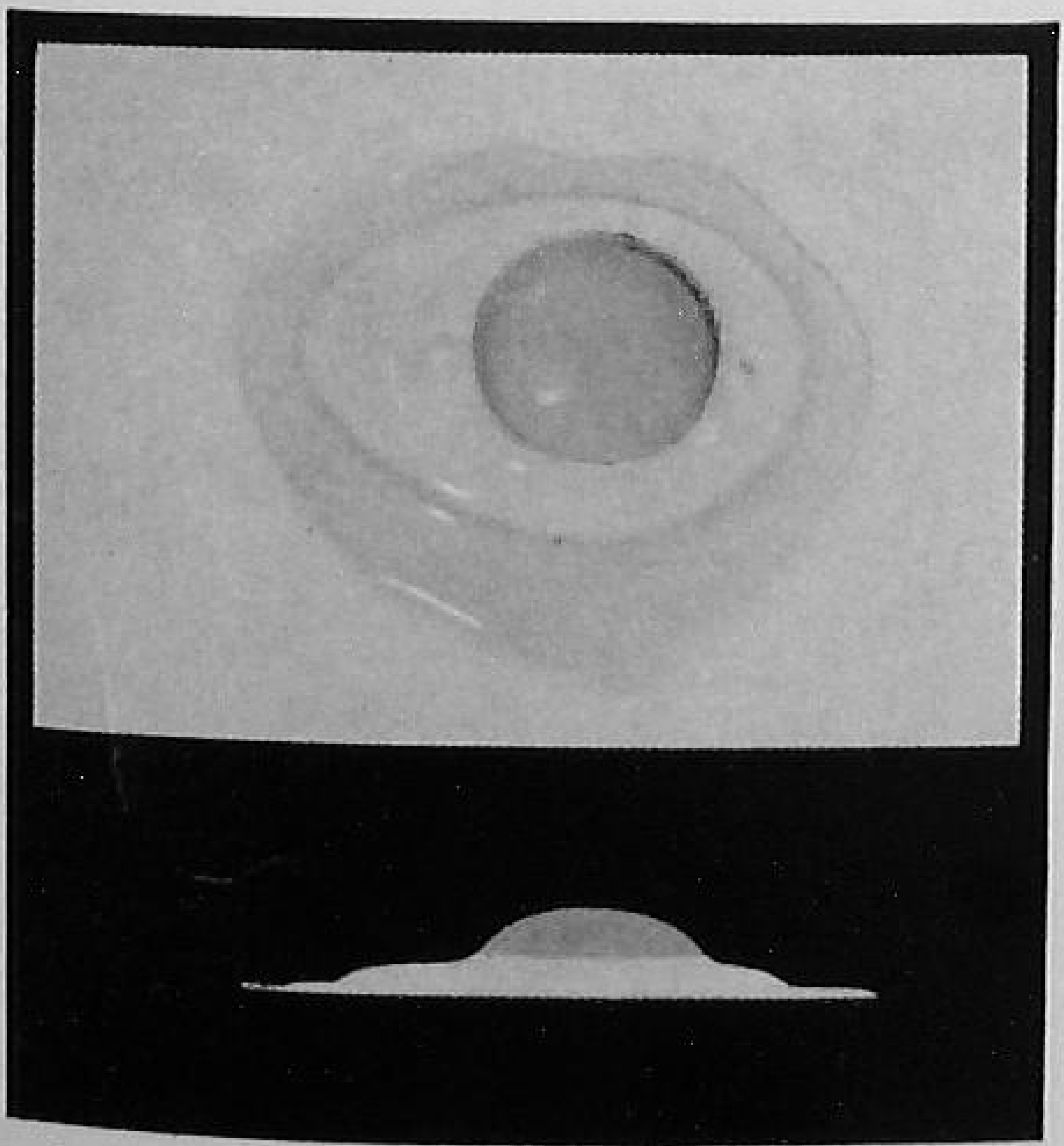
1. Shell—clean; unbroken; practically normal.
2. Air cell—2/8 inch or less in depth; practically regular.
3. White—clear; may be reasonably firm.
4. Yolk—may be fairly well centered; outline fairly well defined; practically free from defects.



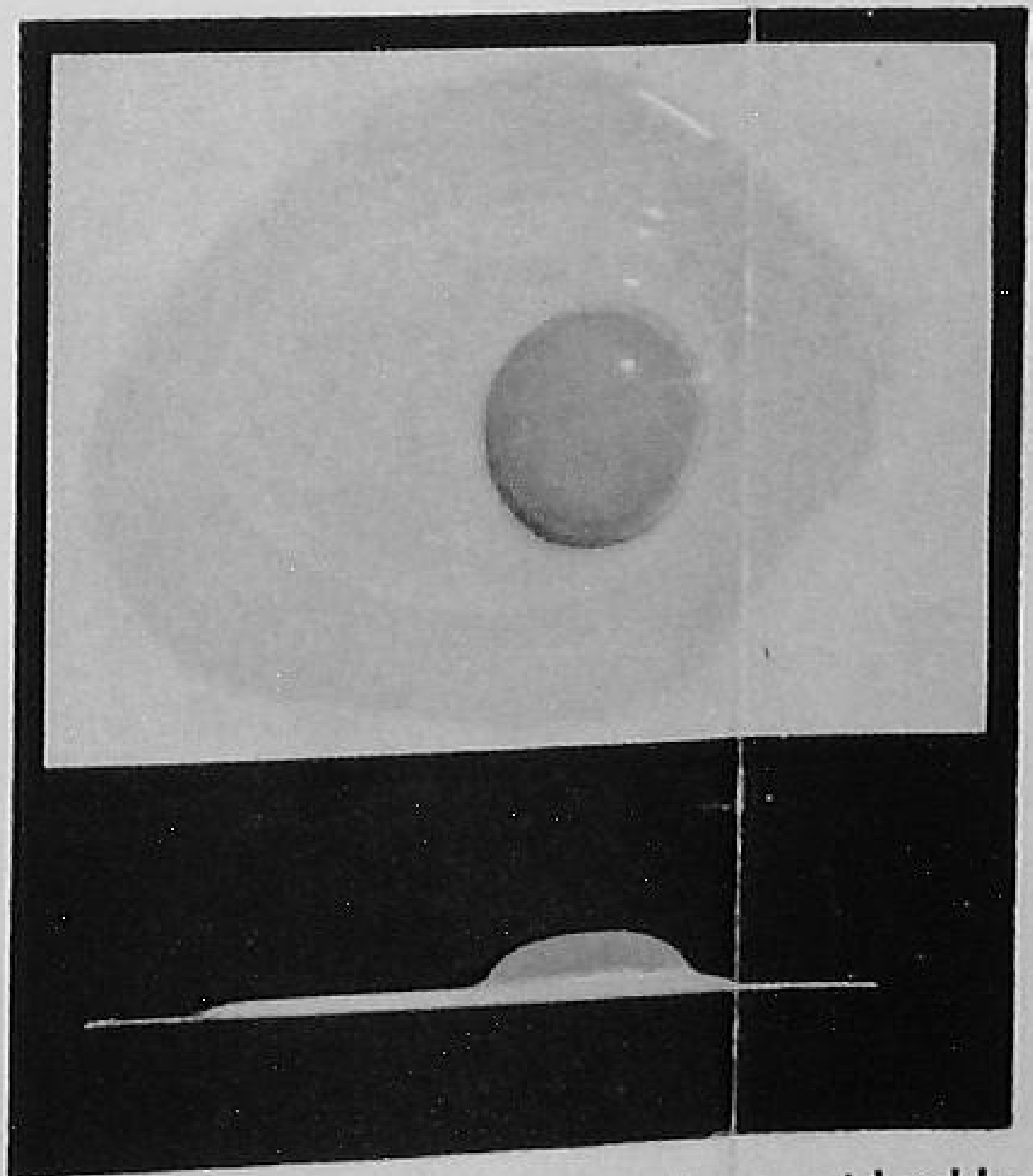
B Quality

1. Shell—clean; unbroken; may be slightly abnormal.
2. Air cell—3/8 inch or less in depth; may show movement not over 3/8 inch; if not over 2/8 inch, may be free.
3. White—clear; may be slightly weak.
4. Yolk—may be off center; outline well defined; may be slightly enlarged and flattened; may show definite but not serious defects.

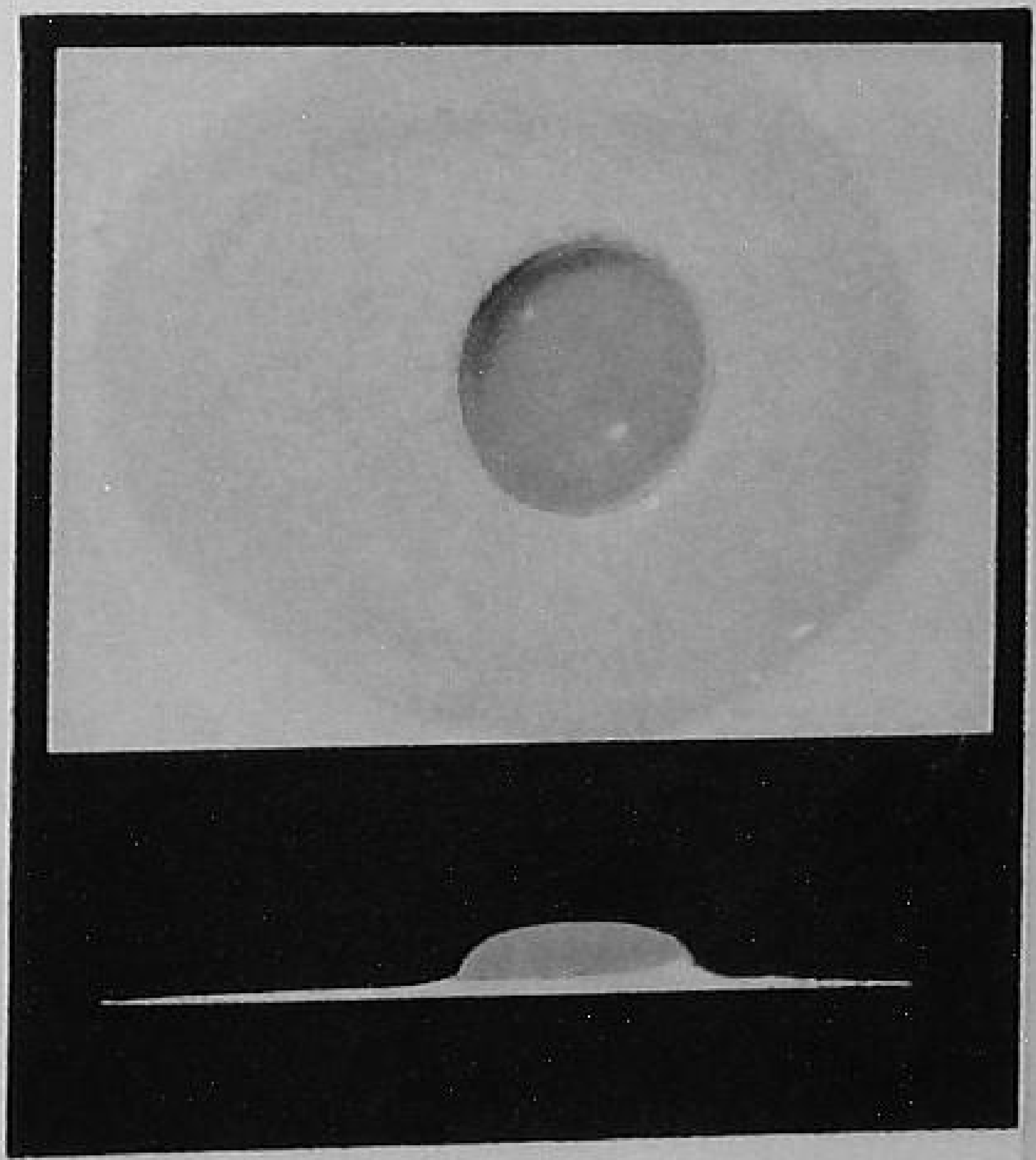
Illustrations of broken-out appearance (top and side views) of each quality—1/



AA Egg covers small area; much thick white surrounds yolk; has small amount of thin white; yolk round and upstanding.



A Egg covers moderate area; has considerable thick white; medium amount of thin white; yolk round and upstanding.



B Egg covers wide area; has small amount of thick white; much thin white; yolk somewhat flattened and enlarged.

Graders should check their work by breaking out an egg occasionally and comparing it with this chart. U. S. Department of Agricultu

(Color charts—U. S. Standards for Quality of Individual Shell Eggs)

☆U. S. GOV

mining interior quality that are taken into consideration in grading eggs include (1) the condition of the yolk, (2) the condition of the white, and (3) the size and condition of the air cell. By far the most important of these various characteristics that determine grade are the condition of the yolk and the condition of the white, although cleanliness of shell is of paramount importance in enabling eggs to qualify for any of the better grades.

U.S. Standards. The U.S. Department of Agriculture has established standards for individual qualities of eggs that might well serve in the adoption of any grading system. As a matter of fact, many state grades

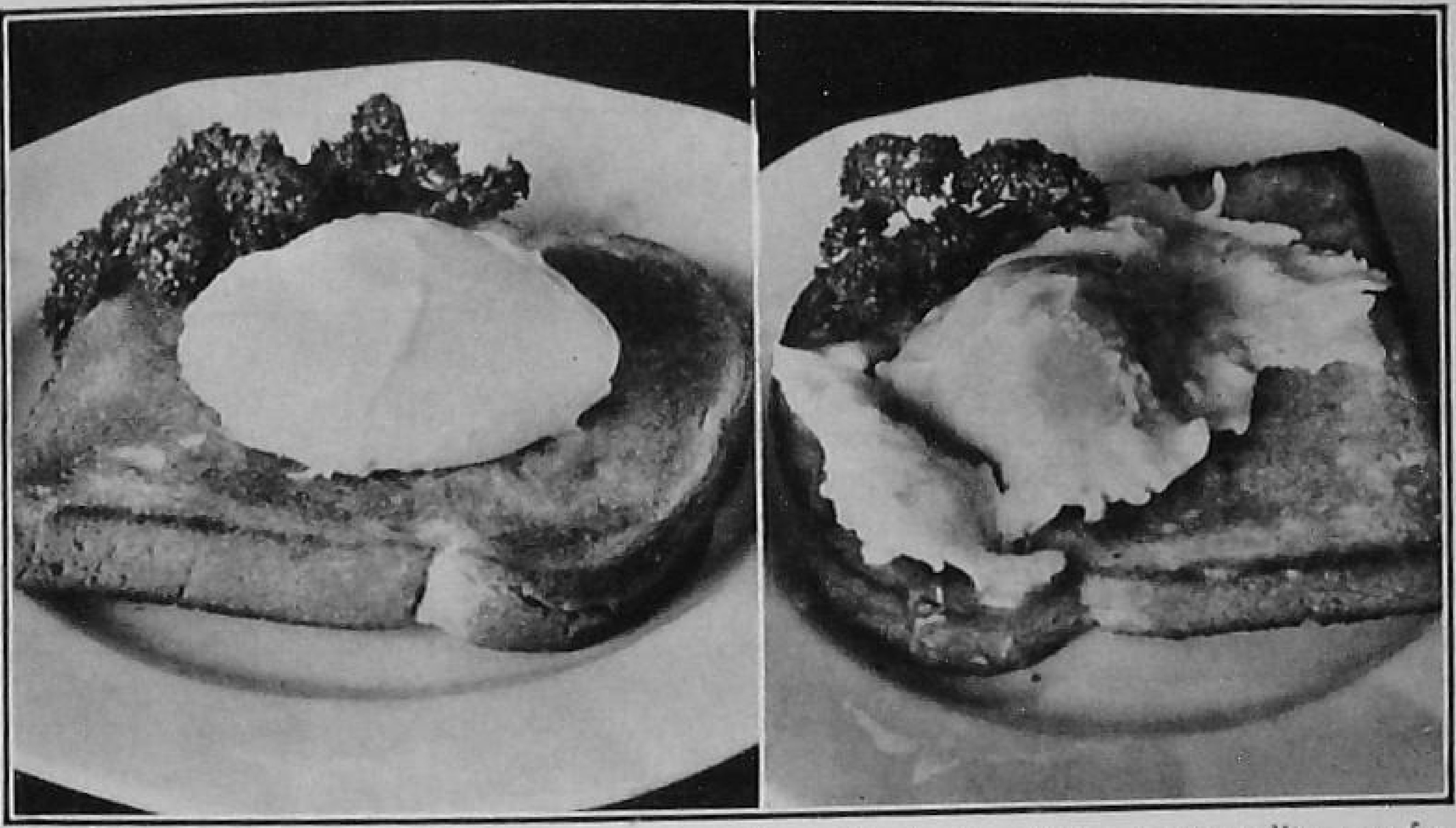


FIG. 208. Left, high-quality egg for poaching, Grade A. Right, poor-quality egg for poaching, Grade C. (*E. S. Snyder, Ontario Agr. Coll.*)

have been adopted based on the Federal standards. A summary of U.S. standards for quality of individual shell eggs is given under the illustrations of shell eggs in color.

The U.S. Department of Agriculture has established tentative specifications for consumer grades of shell eggs based on the U.S. standards for quality of individual eggs. For each grade, certain tolerances are allowed with respect to percentages of eggs of lower grades, but these details need not be discussed in this book. However, the weight classes for consumer grades of shell eggs should be of interest to all producers.

In actual practice, farmers and commercial-egg producers confine their grading of eggs for the most part to size and color. Grading for interior quality is done mostly by egg auctions and other cooperative marketing agencies and by shippers and wholesale-egg dealers.

Egg Grades Used in the Industry. It is obvious that since enormous numbers of eggs are shipped considerable distances from areas of produc-

tion to centers of consumption, it would be in the best interests of producers, distributors, and consumers if eggs were bought and sold on a uniform basis throughout all parts of the country. There are many different grades of eggs, however, including those established by wholesalers, jobbers, and retailers. The use of so many different grades and classifications of eggs often creates confusion among buyers and sellers. Moreover, since market requirements have become more stringent and since consumers have become more conscious of the importance of quality in eggs, there is an increased need for the adoption of standardized grading methods throughout the country.

WEIGHT CLASSES FOR CONSUMER GRADES FOR SHELL EGGS

Size or weight class	Minimum net weight per dozen, oz.	Minimum net weight per 30 dozen, lb.	Minimum weight for individual eggs at rate per dozen,[a] oz.
Jumbo	30	56	29
Extra large	27	50½	26
Large	24	45	23
Medium	21	39½	20
Small	18	34	17
Peewee	15	28	

[a] Minimum weights listed for individual eggs at the rate per dozen are permitted in various size classes only to the extent that they will not reduce the net weight per dozen below the required minimum, consideration being given to variable weight of individual eggs and variable efficiency of graders and scales which should be maintained on a uniform and accurate basis.

The common practice of buying eggs on the case-count basis has one fundamental weakness; the farmer and commercial-egg producer are given but little incentive to improve the quality of their eggs. The adoption of candling laws in several states prohibiting dealing in inedible eggs and laws in other states prohibiting selling inedible eggs at retail were among the first steps taken to focus attention upon the importance of producing and marketing eggs of the quality wanted by consumers. Gradually more and more buyers have adopted the practice of grading eggs at the time they are received from producers. Paying for eggs according to quality offers an incentive to the producer to improve quality.

One illustration of the benefits of buying eggs from producers on a graded basis is that of an Iowa egg buyer and carlot shipper who decided to pay producers according to the quality of eggs they produced. Producers were encouraged to increase the volume of eggs they produced and to adopt flock-management and egg-marketing practices that would increase the percentage of top grades and producer profits. Each producer was given a number, and his eggs were graded separately. When

the eggs were delivered to the buying station, the producer was paid a flat price per dozen, but at the end of each marketing period the producer was given an accounting showing the volume of each grade delivered, the price of each grade, and the producer was paid an additional amount according to the total value of the various grades delivered. This method resulted in a marked improvement in the quality of eggs produced and profits earned by producers in the community concerned.

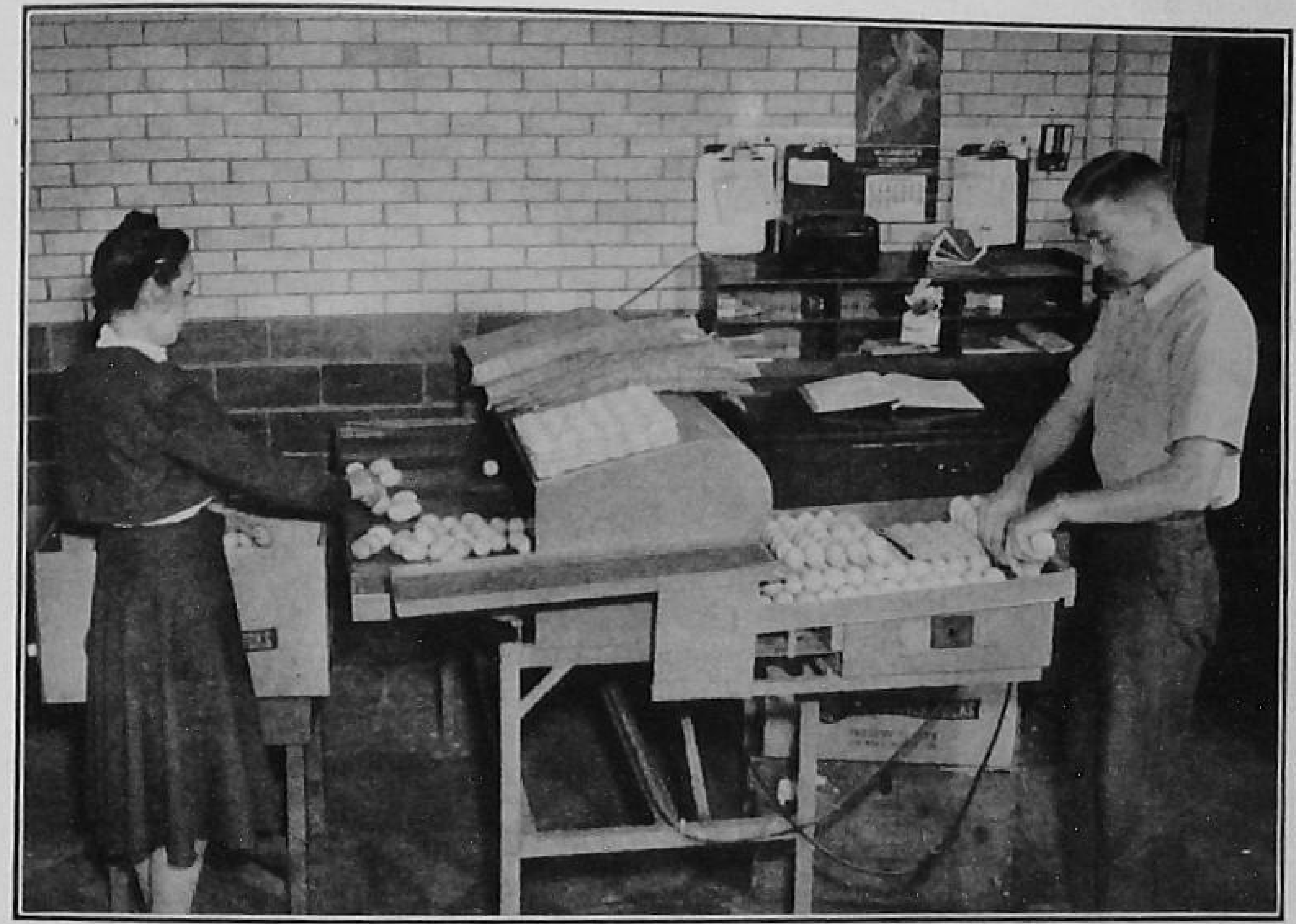


FIG. 209. Egg grader on the poultry plant of G. Ellis in Delaware. (*Hatchery and Feed.*)

Managers of egg auctions and other cooperative marketing agencies, as well as jobbers and wholesalers in increasing numbers, are adopting the practice of buying eggs on a graded basis because they find that, for the most part, better quality eggs are obtained. In many cases, eggs are graded at country receiving centers and packed in cartons under a brand name for delivery direct to retail outlets. Although most retailers buy their eggs already graded, some of them sell their eggs under a few or several brand names.

The inspection of eggs is an integral part of the practice of buying and selling eggs on a graded basis. Inspections are necessary for the purpose of determining the extent to which various shipments of eggs have retained their original grade. Inspection involves the candling of a random sample of the cases of eggs in each shipment. When the inspection is completed, an official grade is placed on the shipment.

PACKAGING EGGS FOR MARKET

During the early years of the development of the poultry industry of the United States and the expansion of the industry westward from the northeastern area, it was customary to pack eggs in kegs or barrels for shipment to the eastern consuming centers. In the stores, the eggs were displayed in tubs or baskets and were sold to customers in the "loose" form, no special packages for each dozen being provided. In many country stores of today, especially in certain sections of the country, eggs are still sold loose without being packaged. For many years, however,

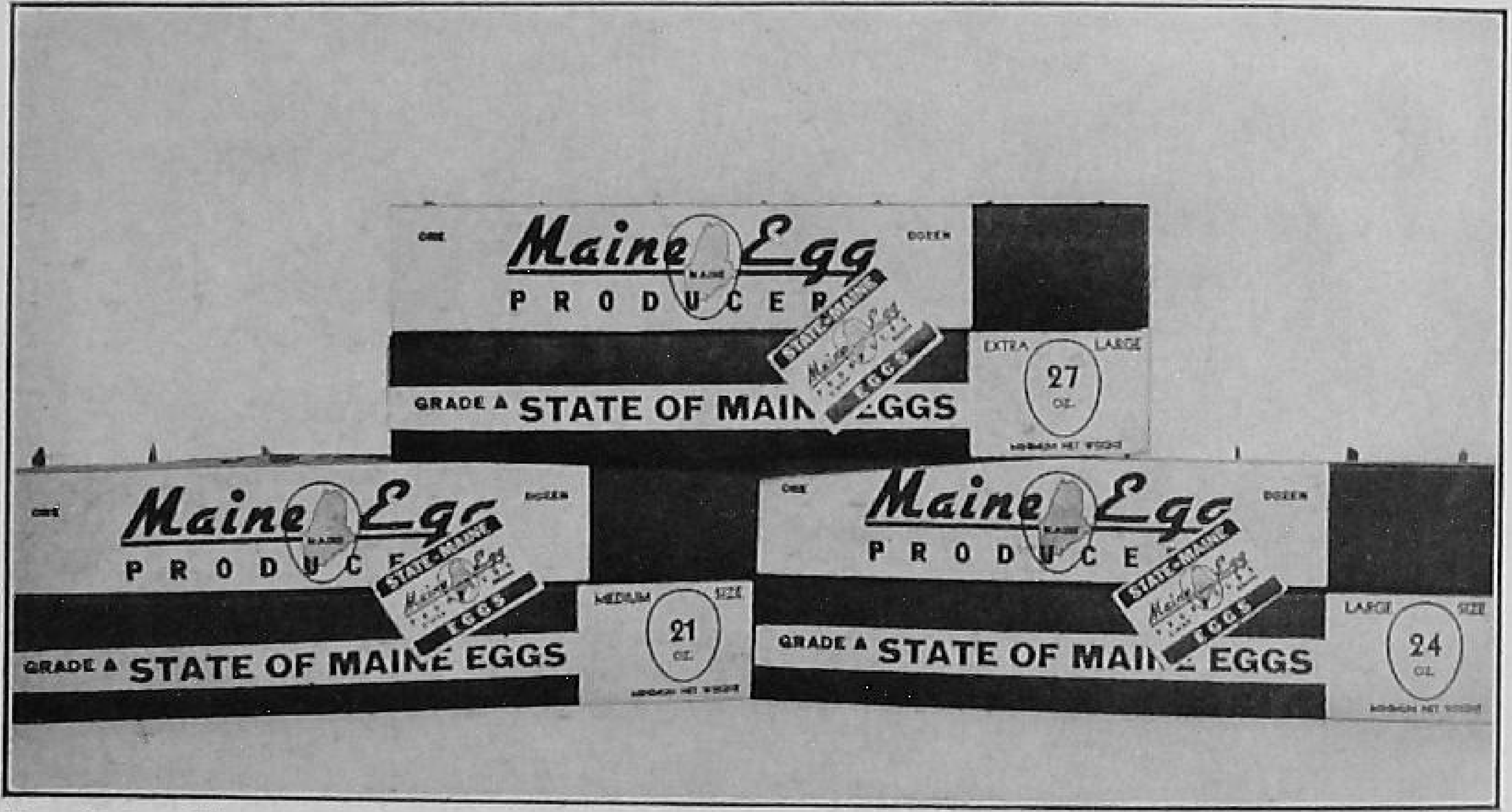


FIG. 210. The printed weight of the dozen in each carton enables the customer to compare the price of eggs with other foods on a weight basis. It would be better still if the weight per dozen were stated in pounds; for instance, instead of 24 oz., use $1\frac{1}{2}$ lb. The customer then has a direct basis for comparing eggs per pound with beef, pork, lamb, and cheese per pound. (*Maine Egg Producers.*)

eggs in the shell have been marketed for the most part in cartons, parcel-post containers, and egg cases. These containers should be well made to avoid breakage of eggs and at the same time light enough to avoid excessive shipping charges.

The railroads and other agencies engaged in the transportation of eggs publish regulations pertaining to egg packages and methods of packaging eggs. Special regulations are published by express and postal authorities governing the shipments of eggs by express and by parcel post.

In Cartons. Cartons are pasteboard containers holding ½- or 1-doz. eggs, in the latter case being made in two styles, one holding three rows of 4 eggs each, and the other holding two rows of 6 eggs each. Cartons are used in selling eggs direct from the producer to the consumer and by the retail trade. Since the carton of two rows of 6 eggs each fits into the

30-doz. egg case, it is used much more frequently than the other style. Usually only 24 cartons are packed in a 30-doz. case, and alternate layers of cartons are placed crosswise. Shell-treated eggs should be sold to consumers in cartons, in order to avoid the possibility of some oil getting onto the dealer's or customer's fingers and to prevent oil coming in contact with other articles.

In Parcel-post Containers. Parcel-post containers are made in various styles and sizes to hold from 1 doz. to several dozen eggs. They should

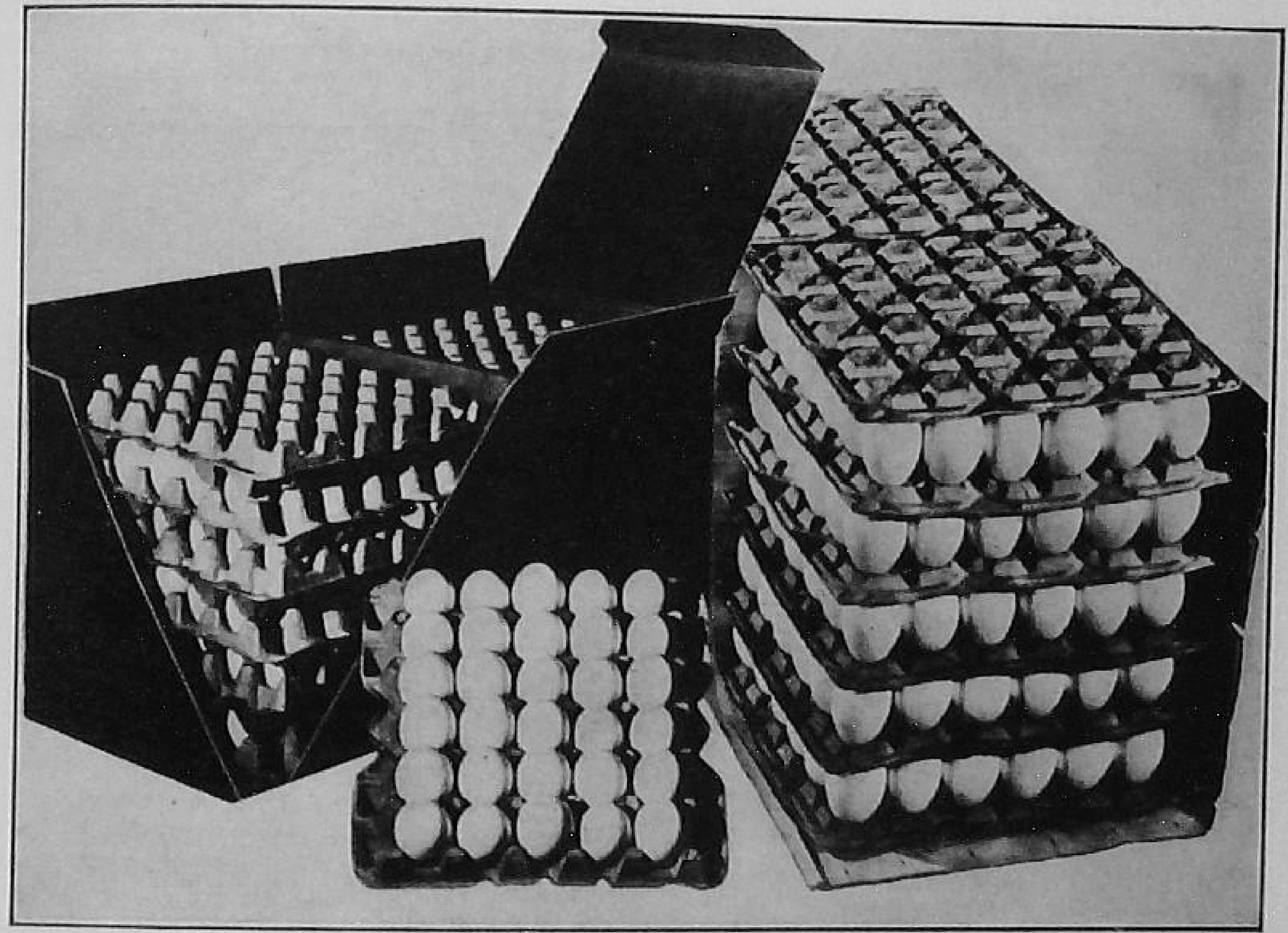


Fig. 211. Showing method of packing eggs in fiber and wooden cases. Note remarkable uniformity of size and shape of eggs. (*Keyes Fibre Sales Corporation.*)

be durable in construction but light enough to keep transportation charges to a minimum. Corrugated cardboard and fiberboard are satisfactory materials for making parcel-post containers. Each package should be plainly marked "Eggs, Handle with Care."

In Wooden Egg Cases. Eggs should always be packed in cases, with the large ends of the eggs up. For many years the 30-doz. egg case was the usual method of packaging large shipments of eggs. The case has a center partition, 15-doz. eggs being packed in each half, which is approximately 12 in. square.

The cases are made preferably of spruce or cottonwood, both of which are light in weight, odorless, and light colored. Fir, gum, hemlock, and other woods may be used. All wooden cases should be nailed thoroughly

with threepenny cement-coated egg-case nails. Each end of the top should be nailed with at least four nails, care being taken to drive the nails into the upright end of the case and not into the cleat.

In Fiber Egg Cases. During recent years the use of fiber egg cases, 15-doz. and 30-doz. sizes, has increased considerably.

Corrugated fiber cases are made of double-faced corrugated fiberboard, there being a sheet of fiberboard on each side of a corrugated medium. The tops, sides, ends, centers, and bottoms are usually made of two thicknesses of corrugated fiberboard; sometimes the ends are made of three thicknesses and the bottoms of four thicknesses.

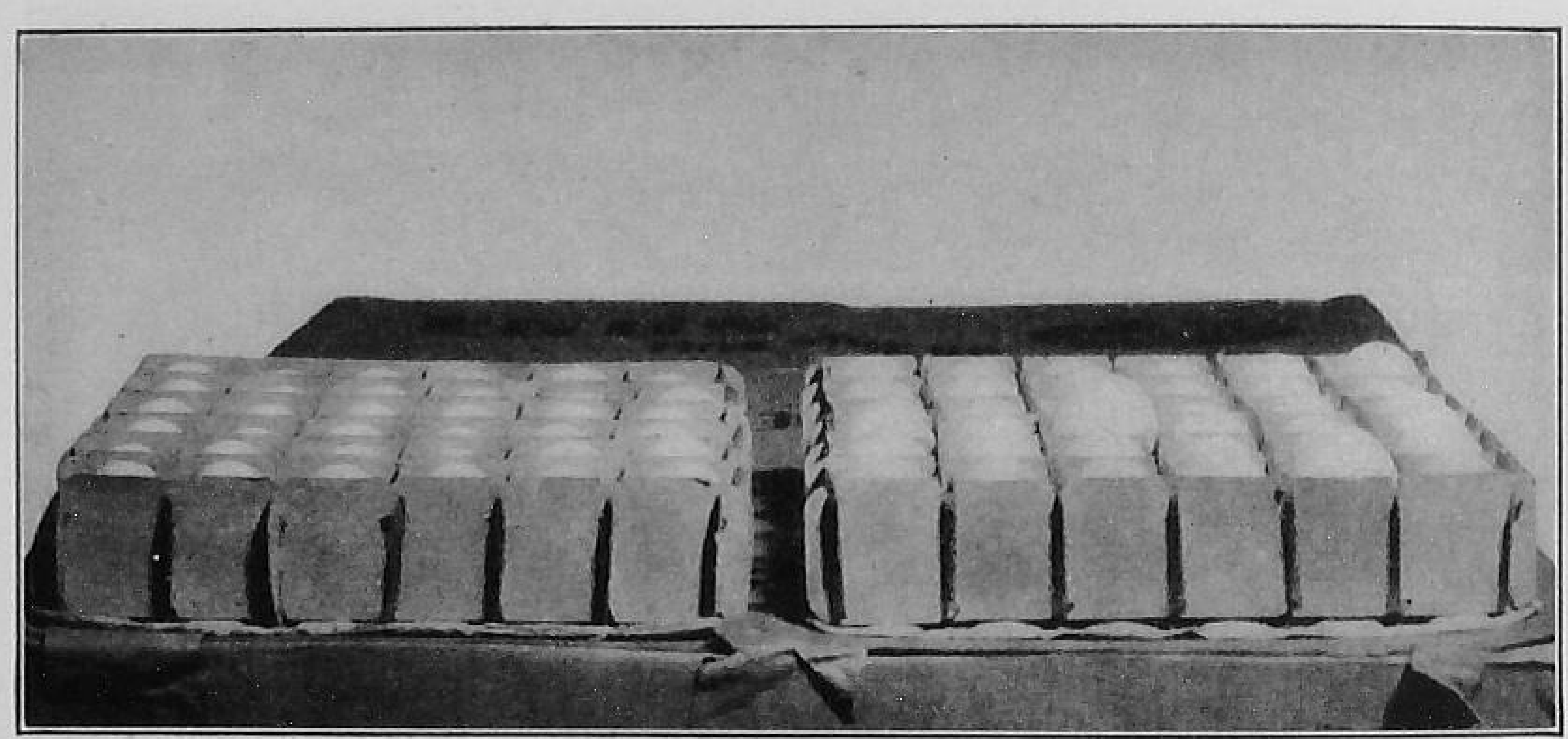


FIG. 212. Extra-large eggs packed in a case frequently become broken, the broken contents spoiling flats and fillers for reuse. (*U.S. Dept. Agr.*)

Solid fiber egg cases are made of at least three plies of fiberboard glued together. One thickness is usually used for the sides and two or three thicknesses for the tops, ends, centers, and bottoms.

Egg-case Liners, Flats, and Fillers. In packing eggs in the 30-doz. egg case, it is advisable to use egg-case liners, which should be moisture-proof and impervious to air. The use of these liners helps to prevent the absorption of odors and flavors by the eggs, retards loss of water from the egg, and tends to retain carbon dioxide, thus tending to retard deterioration in egg quality.

Filler flats, or other types of flats, and honeycomb fillers are used to pack eggs in the right and left halves of a 30-doz. egg case. A filler flat holds 30 eggs, six layers being packed in each half of the case. Each filler flat is made with an indenture on the middle of each side for inserting the hands to lift the tier of eggs from the case. Each layer of filler flats has the hand holes on alternate sides of the half of the case. The use of flats to support each layer of eggs and honeycomb fillers to keep

the eggs of each layer separated from each other has long been a standard practice of packing eggs in 30-doz. egg cases. Each layer contains 36 eggs, there being five layers in each half. The embossed flat makes a very desirable type of flat because the raised portions of each flat provide a cushion to support each egg, the honeycomb fillers fitting quite snugly over the flat.

Brand Name on Cases. It is a common practice for many egg-producing organizations and packers to place a brand name on the end of the case, the brand name bearing the name of the organization or the packer, or the grade of eggs, or both the brand name and the grade.

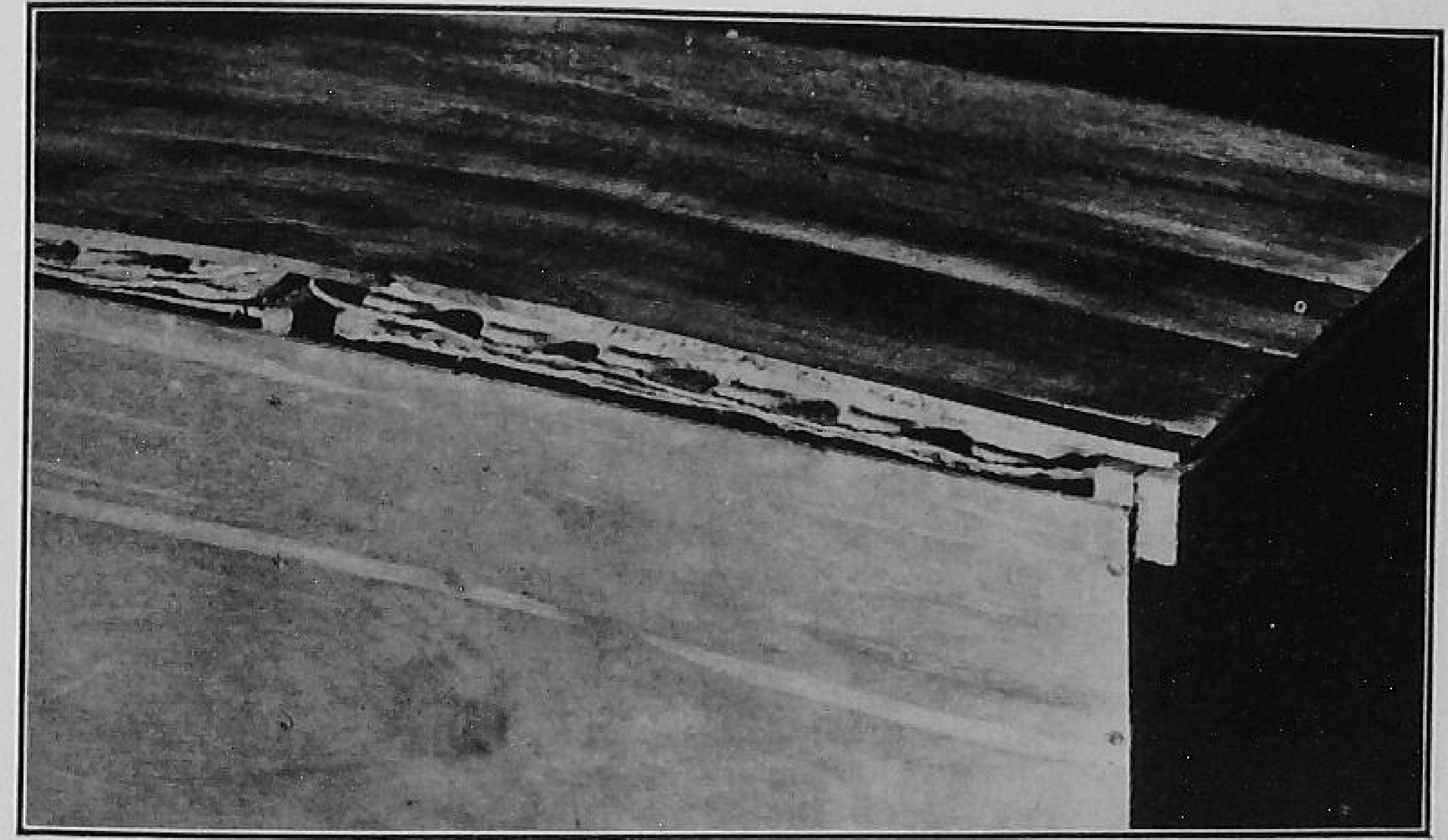


FIG. 213. Using an extra inverted flat on the top of each compartment in a case that contains eggs weighing from 36 to 49 lb. net per case helps to reduce egg breakage. (*U.S. Dept. Agr.*)

MARKETING PROBLEMS IN RELATION TO PRODUCTION

Although eggs are produced in all parts of the United States, the problem of marketing them varies a great deal in different sections, and there are seasonal marketing problems as well. The most important egg-consuming centers are located in the highly industrialized sections of the country. The smaller cities throughout all parts of the country secure a large share of their annual egg requirements from nearby areas, but the larger cities must rely in addition on the more important producing areas for their supply. There are sections of the country where eggs are produced in excess of local requirements at all times of the year and especially so at certain seasons. The biggest problem in marketing eggs, therefore, is one of transporting surpluses from the various producing areas to the largest consuming centers.

Geographical Distribution of Production. In Table 2, Chap. 1, a list is given of the 15 most important egg-producing states for the period 1942 to 1946. A glance at the "egg-production" map in Fig. 214 shows that the "egg belt" starts in the East with New York and passes westward through the contiguous states of Pennsylvania, Ohio, Indiana,

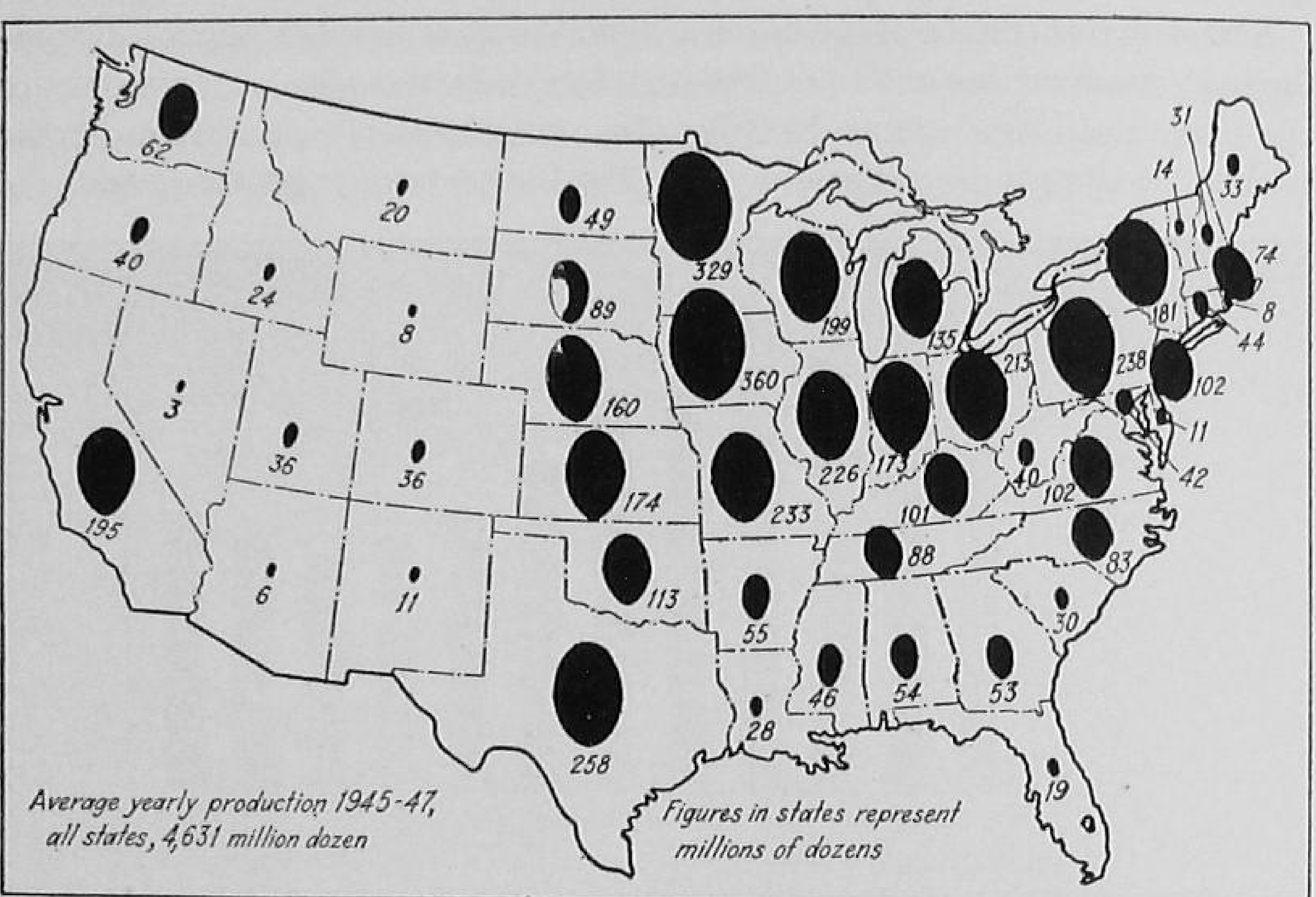


FIG. 214. Showing the average yearly egg production by states during 1945 to 1947.

TABLE 47. RECEIPTS OF SHELL EGGS AND FROZEN EGGS AT FOUR MARKETS, BOSTON, CHICAGO, NEW YORK, AND PHILADELPHIA, BY STATE OF ORIGIN, 1947
(Production and Marketing Administration, U.S.D.A.)

State	Shell eggs, cases	State	Frozen eggs, lb.
Iowa	3,454,531	Iowa	21,999,695
Minnesota	2,807,089	Illinois	19,995,312
Wisconsin	1,518,206	Minnesota	17,995,818
Pennsylvania	1,209,296	Missouri	12,790,211
New York	1,064,230	South Dakota	11,454,590
Illinois	714,602	Nebraska	10,040,436
Indiana	602,153	Kansas	7,928,841
Massachusetts	358,688	Indiana	6,658,575
New Jersey	337,280	North Dakota	4,204,183
Ohio	222,793	Texas	2,650,318
Total	13,507,371	Total	124,775,968

Illinois, Missouri, Kansas, Nebraska, Iowa, Minnesota, Wisconsin, and Michigan. The two most important egg-producing states outside of the "egg belt" are Texas and California.

The large consuming population of the highly industrialized northeastern sections of the country depend on the "egg-belt" states for a high percentage of its eggs. The extent to which this is true is indicated by the data in Table 47 giving the 1947 receipts of shell eggs and frozen eggs at Boston, New York, Philadelphia, and Chicago. The 10 states listed as major sources of shell eggs for these cities supplied about 91 per cent of the total receipts and among those 10 states, 8 are in the "egg belt." The 10 states listed as major sources of frozen eggs supplied about 93 per cent of the total receipts, and 7 of the 10 states are "egg-belt" states, the other 3 being South Dakota, North Dakota, and Texas.

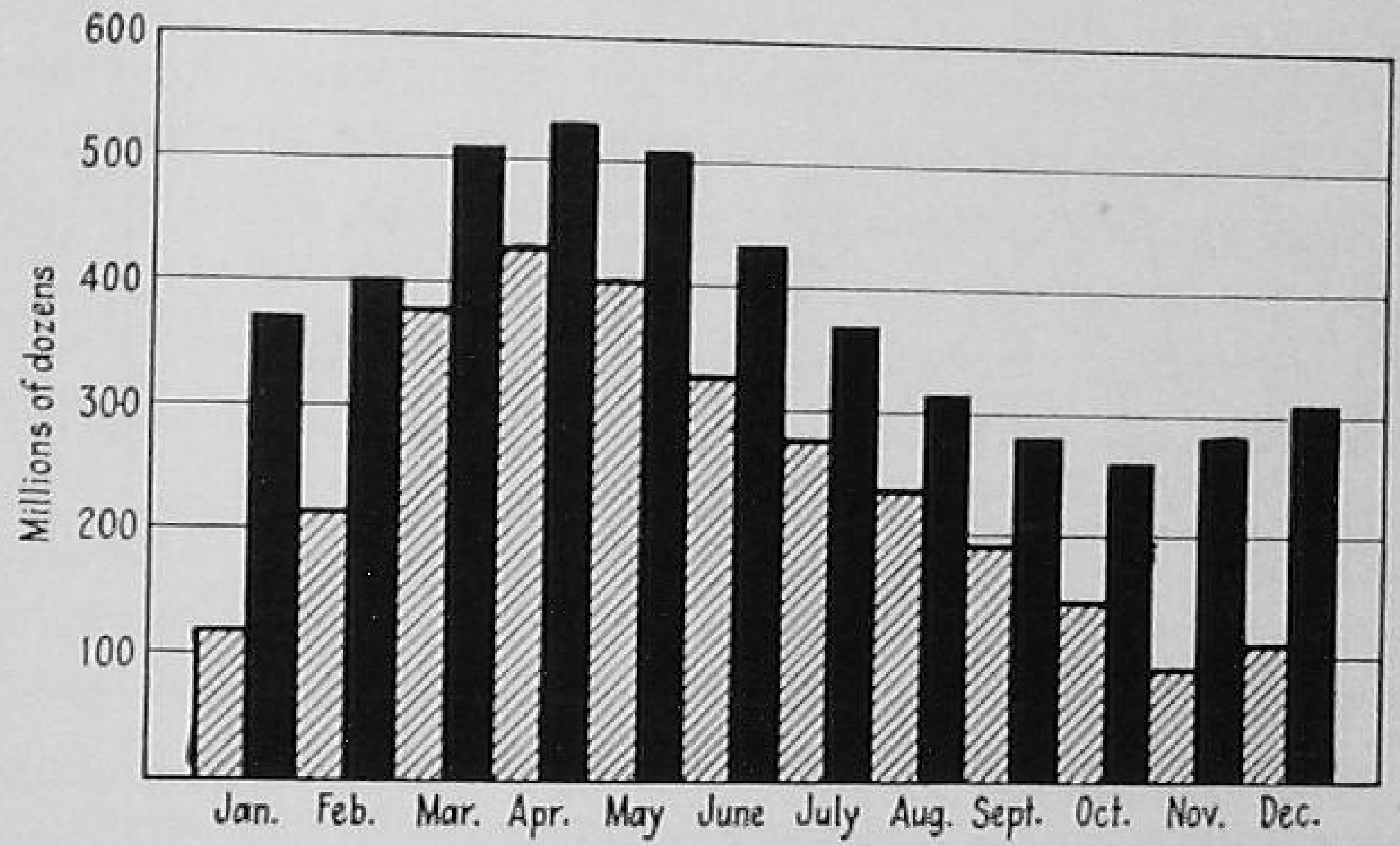


FIG. 215. Millions of dozens of eggs produced by months in 1925 (striped bars) and in 1947 (black bars). In 1925 about 53 per cent of the year's production was laid in March, April, May, and June, whereas in 1947 about 43 per cent of the year's production was laid in the same 4 months. Note particularly the higher proportion of eggs laid in the fall and winter months in 1947 than in 1925.

Seasonal Levels of Production. A problem of particular importance in the marketing of eggs pertains to the relatively high proportion of eggs that are produced during the spring months. Rate of lay is higher at that season than at any other time of the year, as indicated in Fig. 215. In 1947, the number of eggs produced during March, April, May, and June amounted to about 43 per cent of the total number of eggs produced during the year.

The marketing of such large quantities of eggs during the spring months presents a serious problem in all parts of the country, especially in those states with relatively large volumes of production. Since the per capita consumption of eggs remains fairly stable month by month throughout the year, especially in important consuming centers, a good

proportion of the spring egg production must be placed in storage to make up for the relative deficit production during the fall and early winter months.

An examination of Fig. 216 shows that shell eggs are placed in cold storage, for the most part, during February, March, and April and are taken out of storage during July to December. Frozen eggs, for the most part, are placed in cold storage during March, April, and May and are taken out largely during August to January. Placing the "extra" spring egg production in cold storage, either in the form of shell eggs or frozen eggs, helps to stabilize the egg market at that season of the year and also

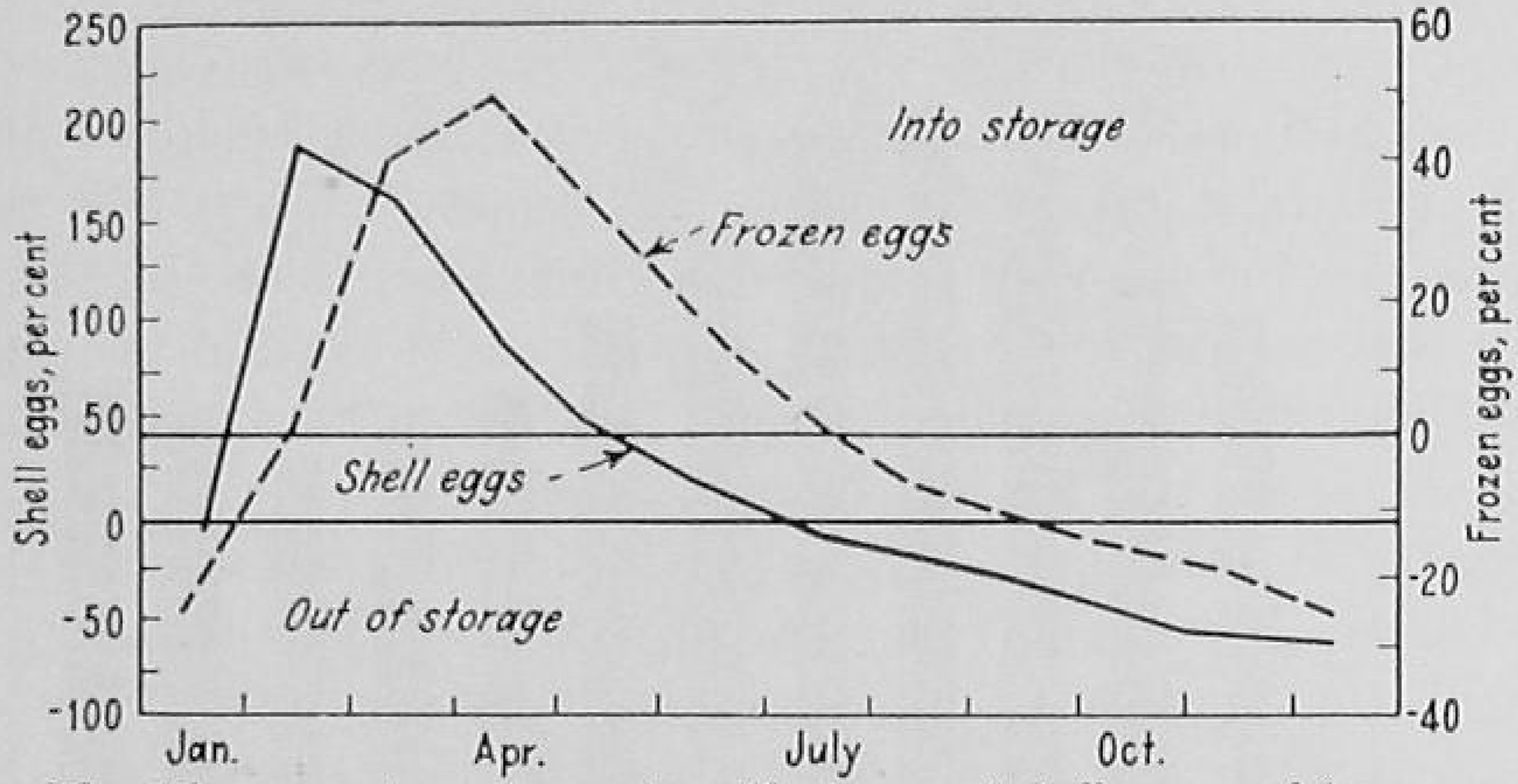


FIG. 216. Monthly percentage change in cold storage of shell eggs and frozen eggs, 1943 to 1947 average. (*Production and Marketing Administration, U.S. Dept. Agr.*)

supplies consumers and manufacturers of various food products with eggs during the relatively deficit season of production, the late summer and early fall months.

During recent years the percentage of the annual egg crop placed in cold storage has been relatively smaller than in former years. This is due to the higher rate of laying in the fall and early winter months than formerly and to the expansion of the frozen-egg industry. Also, in recent years more consumers have been able to afford fresh shell eggs in October, November, and December.

SHELL-EGG MARKETING METHODS

The methods of marketing eggs from the producer to the consumer are many and varied, depending largely upon the number of channels through which the eggs are obliged to pass before reaching the consumer. The method of marketing employed affects the quality of the eggs as they reach the consumer and the price paid to the producer. The more direct the method of marketing, the less the eggs have to be handled, the less the delay, and usually the less the cost of marketing.

Direct to Consumer. Many producers market their eggs direct to the consumer or to a hotel, restaurant, or retailer, this method being followed quite extensively by commercial poultrymen in the vicinity of good markets. Eggs are sometimes delivered by truck or shipped by parcel post, express, or freight. The two important factors that determine whether or not eggs can be sold by the direct method are the ability of the producer to provide a regular supply of high-quality eggs from week to week and the costs of delivering or shipping.

Many farmers who maintain roadside "stands" sell considerable quantities of eggs, the marketing expense being very low.

To Hatchery Operators. In some sections of the country, hatchery operators make a practice of purchasing fresh-laid eggs the year round from their hatchery-flock owners, the males being removed from the flocks immediately after the breeding season. When the hatchery operator is able to provide suitable holding conditions for the market eggs he receives from flock owners and is able to market the eggs profitably, this marketing arrangement works to the mutual advantage of the hatchery operators and his hatchery-flock owners.

To Country Storekeeper. Many producers sell their eggs to the country storekeeper or exchange the eggs for goods. This method, however, is gradually being replaced by others more satisfactory. The country storekeeper is often not in a position to hold his eggs under conditions suitable for the preservation of the superior quality desirable in market eggs. Moreover, most storekeepers do not differentiate between good and poor quality in eggs but pay producers the same price for all eggs received and thus offer the producer no incentive to produce high quality.

Cooperative Marketing. In various parts of the United States associations of producers have been formed for the purpose of marketing the eggs of their members. More recently the cooperative movement has been developed along the lines of egg auctions.

Cooperative-marketing organizations must comply with certain government regulations pertaining to membership and management, but they enjoy advantages with respect to the freedom from certain taxes.

The ability of a cooperative egg-marketing organization to operate efficiently and successfully depends upon a number of conditions, including (1) the need for the development of a cooperative-marketing method, (2) a sufficient volume of eggs and a sufficient number of cooperators to carry the necessary overhead without undue expense and to permit the securing of the most desirable outlets for the eggs, (3) concentrated production to reduce the costs of handling to the minimum, (4) efficient management, and (5) a type of organization that is able to stand the stress and strain of the competitive-marketing system.

Some of the largest and most successful egg-marketing cooperatives are those located on the Pacific Coast, in the Rocky Mountain states, in the Middle West, and in the Northeast.

In some respects the most interesting development in cooperative egg marketing that has taken place in the United States during the past decade has been the formation of country-point egg auctions. They have enjoyed a relatively rapid growth, are located for the most part in the Northeastern states, and have been established mostly in areas of comparatively heavy egg production which are within easy reach of the large consuming centers. The auction method of marketing makes it possible to sell eggs at relatively low overhead costs and assures the securing of good prices, largely because competition is developed among buyers. The service rendered by the auctioneer is a very important factor in the success of an egg auction. In most instances, the egg auctions have been the means of raising the price level of eggs in the district in which the auction is established.

The auction method of selling eggs was apparently developed chiefly as the result of the competition on the New York City and other eastern markets for the superior quality eggs produced by the members of the Pacific Coast and other western cooperative organizations. During recent years, highly successful cooperative egg auctions, handling large volumes of eggs annually, have been developed in the northeastern section of the country. The fundamental objective in the development of the auction method of selling was to induce the producers in the Northeast to improve the quality of their eggs so that higher prices and greater profits might be realized. In most cases, the objective has been accomplished to a marked degree.

The eggs are brought to the auction salesroom where they are inspected by official inspectors and labeled according to grade. The prospective buyer, therefore, has confidence concerning the quality of eggs on which he wishes to bid. The grades set up by the egg auction follow the Federal standards closely. The concentration and grading of large volumes of relatively high-quality eggs at central points has made possible the development of an efficient and orderly marketing system combined with low overhead costs.

The success achieved by the auction method of selling has been accounted for by three sets of conditions existing in the area where the auction has been developed: (1) a relatively large volume of eggs produced within a small radius, (2) relative nearness to large consuming centers, and (3) the patronage of a large number of buyers. Under these conditions the auction associations have been able to obtain sufficient quantities of high-quality eggs to attract buyers who have been willing to pay

the premium that a high-quality product warrants. Not only has the auction method of selling enabled the producers who sell through the auction associations to obtain higher prices for their eggs, but the average price of all eggs produced in the area has been advanced. Hucksters and local buyers who purchase eggs from nonauction members usually pay prices based on the auction-price quotations.

Hucksters. In many sections of the country hucksters gather eggs from farm to farm, a method of marketing having an advantage in being regular as compared with that of producers taking their eggs to the country store any time they wish. Selling eggs to hucksters, however, has the disadvantage that often no premium is paid for quality. Moreover, conditions under which many hucksters transport eggs about the country tend to hasten their deterioration.

Local Buyers. There are local egg buyers located in small towns in practically all parts of the country whose business it is to buy eggs from local sources of supply, collect them in their receiving plants, and pack them for shipment. Since the average shipper does a relatively large volume of business, he is able to buy eggs on a graded basis and thus provide an incentive to the producer to produce good-quality eggs. Unfortunately, however, many local egg buyers do not buy eggs on a graded basis.

Packing Plants. Throughout the Middle West are located large egg and poultry packers who buy eggs from producers, storekeepers, hucksters, and local buyers. Some packing-plant operators use their own trucks, some of which are insulated and carry ice and are equipped with electric fans, for collecting eggs from producers. The egg- and poultry-packing plant thus constitutes the principal concentration agency of a large egg-producing area. The eggs are packed and are then usually shipped in carlots to the principal receiving markets, a carload containing about 400 cases. Cars from the Pacific Coast states usually contain 600 cases. Since aluminum reflects heat, aluminum-sheeted cars are used to some extent for shipping eggs to distant markets. The cars have facilities for ice packing or refrigeration, precooling before loading being very necessary. Because the egg and poultry packer buys eggs in such large quantities, he is able to buy on a graded basis, though very often he does not do so. Buying eggs from the producer on a graded basis stimulates the production of a higher grade of eggs than is otherwise the case.

Jobber or Wholesaler. Certain producers ship their eggs direct to the jobber or wholesaler located at the terminal markets in the larger cities. Wholesale receivers consist of commission merchants and wholesale dealers, the commission merchant operating on a commission basis,

whereas the wholesale dealer buys the eggs and then sells them, taking a chance on a margin of profit. The producer who sells direct to the jobber or wholesale receiver is saved the trouble of establishing and maintaining contacts with the consuming trade, but this method of marketing sometimes returns less to the producer than other methods.

Trading in Futures. It has been pointed out previously that there are seasonal levels of egg production, relatively the greatest production occurring in the spring months and the lowest production occurring during the late summer and early fall months. It has also been pointed out that the "extra" production during the spring months must be stored in refrigerator warehouses for sale during the late summer and early fall months.

There is usually a certain amount of risk involved in buying eggs during the flush season of production in order to store and sell them later in the season when the supply of fresh-laid eggs is relatively scarce. The risk involved is due to the fact that no one knows whether the price of eggs in the late summer and fall will be high enough to cover the cost of the eggs and the cost of storing them and still provide the dealer a reasonable profit. In order to lessen the risk involved, the practice of trading in "futures" has been developed. Trading in futures serves as a balance wheel in the marketing of eggs and renders a service to the poultry industry in general.

Retailing Eggs. Most of the market eggs are retailed by chain stores, independent stores, and, to a less extent, by specialized stores that sell eggs and dairy products primarily. The method of holding and displaying eggs varies a great deal among stores. Eggs are usually sold by the carton or half carton, and they should be held in a refrigerator at about 50°F. The best method of displaying eggs is in a refrigerator display case.

It would be in the best interests of the poultry industry if each carton of eggs carried a label indicating the weight of the dozen in the particular carton. The weight could be stated in terms of ounces per dozen or, better still, in terms of pounds per dozen. For instance, if a carton containing eggs weighing 24 oz. per doz. carried a label stating that the eggs weighed 1½ lb., most consumers would be favorably impressed with the relative price of eggs at so much per pound as compared with the price per pound of red meats that usually prevail.

Summary of Marketing Channels. The problem of assembling eggs in producing areas and shipping them to towns and cities for distribution among consumers is a complicated one, especially when eggs are handled by one or more groups of collectors, shippers, and distributors. The numerous channels through which eggs are marketed are shown in Fig.

217, with the estimated percentage marketed through each agency in 1939. It will be observed that at almost every stage of marketing two or more agencies compete for the available supply of eggs. At the same time, the major share of eggs pass through the main channel, which includes the packing plants (shipper-owned buying stations), shippers,

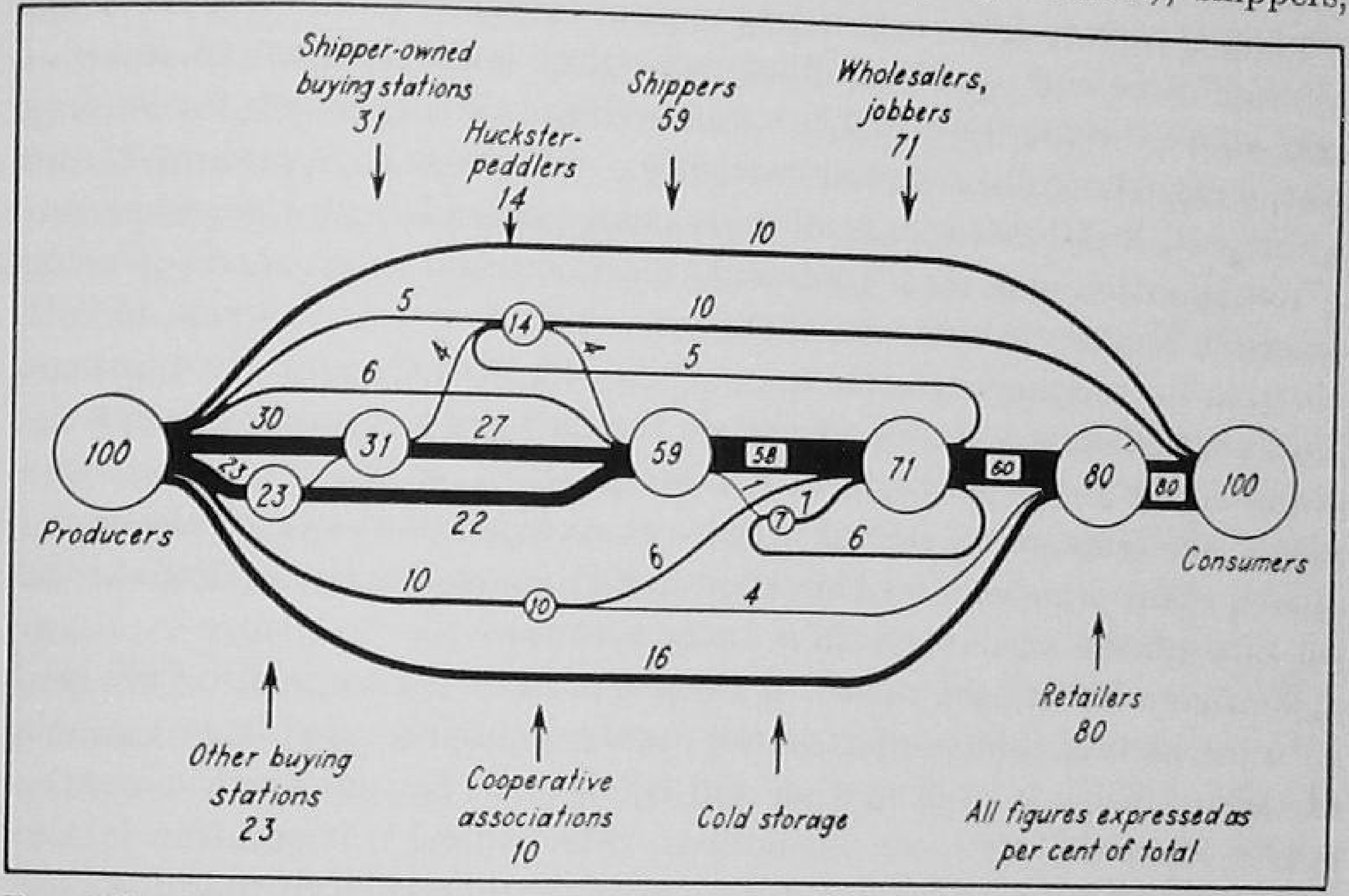


FIG. 217. Egg-marketing channels. Important volumes of eggs move through each of several channels, although the main flow is through country buying stations, shippers, wholesalers and jobbers, and retailers. (*E. P. Winter*, 1948.)

wholesale jobbers, and retailers. These agencies also receive eggs from other sources, as indicated in Fig. 217. A considerable volume of eggs passes from producers through a single agency to retailers. On the other hand, other eggs sometimes pass through several agencies before reaching the retailers through whom the eggs are finally distributed to consumers.

EGG-TRANSPORTATION PROBLEMS

Eggs in the shell are a highly perishable product and are subject to excessive breakage if packed carelessly and handled roughly. Transporting eggs at the least possible cost from producing areas to consuming centers with a view toward providing consumers with eggs of the highest possible quality is a tremendous problem. Eggs are transported by rail, truck, boat, and parcel post, with railroads and trucks hauling by far the major share.

Railroads. Eggs that are to be shipped considerable distances by railroad are often sent by fast freight, a method which tends to conserve

egg quality. Refrigerator cars, preferably surfaced on the outside with aluminum sheeting, but always provided with adequate refrigeration, are necessary to prevent excessive deterioration in egg quality. The cars should always be chilled before being packed with eggs.

Properly precooling the car and packing it with properly chilled eggs are two necessary steps in shipping eggs in refrigerator cars. Also, each car should be equipped with floor racks that keep the bottom cases of eggs above the floor level. The specifications of the railroads for loading cars of eggs should be followed implicitly. The cases of eggs should form a compact, well-braced unit, all cases being placed lengthwise of the car.

Refrigeration with ice is commonly used, cracked or crushed ice being placed in bunkers at each end of the car. The downward current of cold air from the melting ice forces the warm air upward through the bunkers. This continuous circulation of the air through the melting ice keeps the air cool, the desirable temperature being about 40°F. For long shipments, the bunkers are refilled with ice at specified places along the route. Built-in fans are sometimes installed in refrigerator cars to circulate the air through the ice bunkers from bottom to top.

Refrigeration of cars, involving the use of brine tanks, is also provided by a mechanical compression system, power being supplied from the axle of the car when it is in motion and by electric current from a nearby source when the car is not in motion. Mechanical refrigeration is also accomplished by running a Diesel engine continuously to maintain the refrigeration system at a constant temperature.

Express Service. The Railway Express Agency provides facilities for shipping eggs relatively short distances in less-than-carload lots (L.C.L.) Sometimes several L.C.L. shipments are assembled at one point and converted into carload shipments in order to take advantage of lower shipping rates for further shipment to a distant market.

Trucks. During recent years many more eggs have been transported by trucks than by railroads. The refrigeration of trucks to prevent deterioration of eggs in transit is provided in a manner similar to that in railroad cars. Egg cases should be placed lengthwise in trucks. For long-distance hauling, regular schedules are followed, and sleeping quarters provided for relief drivers. One illustration of the distance which eggs may be transported by truck is the large quantity of eggs trucked annually from different places in Minnesota to Baltimore, Md.

Boats. Eggs are sometimes shipped from one seaport to another seaport, although the number of eggs shipped by this method within the United States is very limited. Relatively few eggs are exported to other countries. Refrigeration is usually provided. For shipment within the United States, lower transportation rates by boat as compared with those

by railroad and trucks are usually offset by the relatively longer time required in transit by boat and the fact that the eggs have to be trucked to the boat for loading and from the landing pier to the egg-distributing center.

The Egg-breakage Problem. The number of market eggs broken while in transit to market each year is appalling. Part of this breakage is due to faulty packing by producers; the use of second-hand egg cases; careless handling at shipping and receiving centers; and numerous other factors. During recent years, losses from egg breakage have increased; in 1941, claims for loss and damage amounted to $3.15 per car, whereas in 1945 the figure stood at $28.80 per car. In 1944, the railroads alone paid claims of about $650,000 for damage to shell eggs in transit.

Producers, buyers, shippers, and receivers, by exercising more care in handling eggs, could materially reduce the excessive annual loss resulting from breakage. Badly damaged egg cases and moldy and soiled flats and fillers should be burned. Eggs packed in combined flats and fillers usually provide better protection against breakage than other types of packaging. In packing cartons of eggs in cases, the bottom tier of cartons should be placed lengthwise of the case, with each alternate layer crosswise of the case. Also, a flat placed beneath the bottom tier of cartons and above the top tier of cartons helps to reduce egg breakage. One or more extra flats placed on the top of each compartment of the case in which eggs have not been cartoned helps to reduce the breakage. The raw edges of fiber egg cases should be taped with 3-in. paper tape. Finally, all persons handling cases of eggs should realize that severe jolts and jarring often result in excessive egg breakage.

EGG-MARKETING COSTS

The marketing of the large volume of eggs produced annually in the United States involves the expenditure of enormous sums of money by buyers, shippers, retailers, and others who deal in eggs. Financial facilities must be provided, and risks must be assumed by those who buy and sell eggs. Except for the relatively small quantity of eggs sold direct from producer to consumer and the considerable volume of eggs sold through producer-owned cooperatives, producers are not in a position to assume the responsibility of financing the marketing of their eggs. All agencies who buy eggs at some stage in the marketing channel assume the risk of a change in price depending upon consumer demand in relation to available supplies. Also, since eggs are a perishable product, every buyer of eggs must assume the risk of a change in price due to deterioration in quality from the time the eggs were bought until they

are sold. All transactions in eggs involve a risk, and all dealers in eggs and those who finance the buying and selling of eggs anticipate a reasonable profit. Sometimes profits in marketing eggs are relatively high, the producer receiving no direct benefit, and sometimes losses are excessive, especially in the case of those who buy eggs for storage. By and

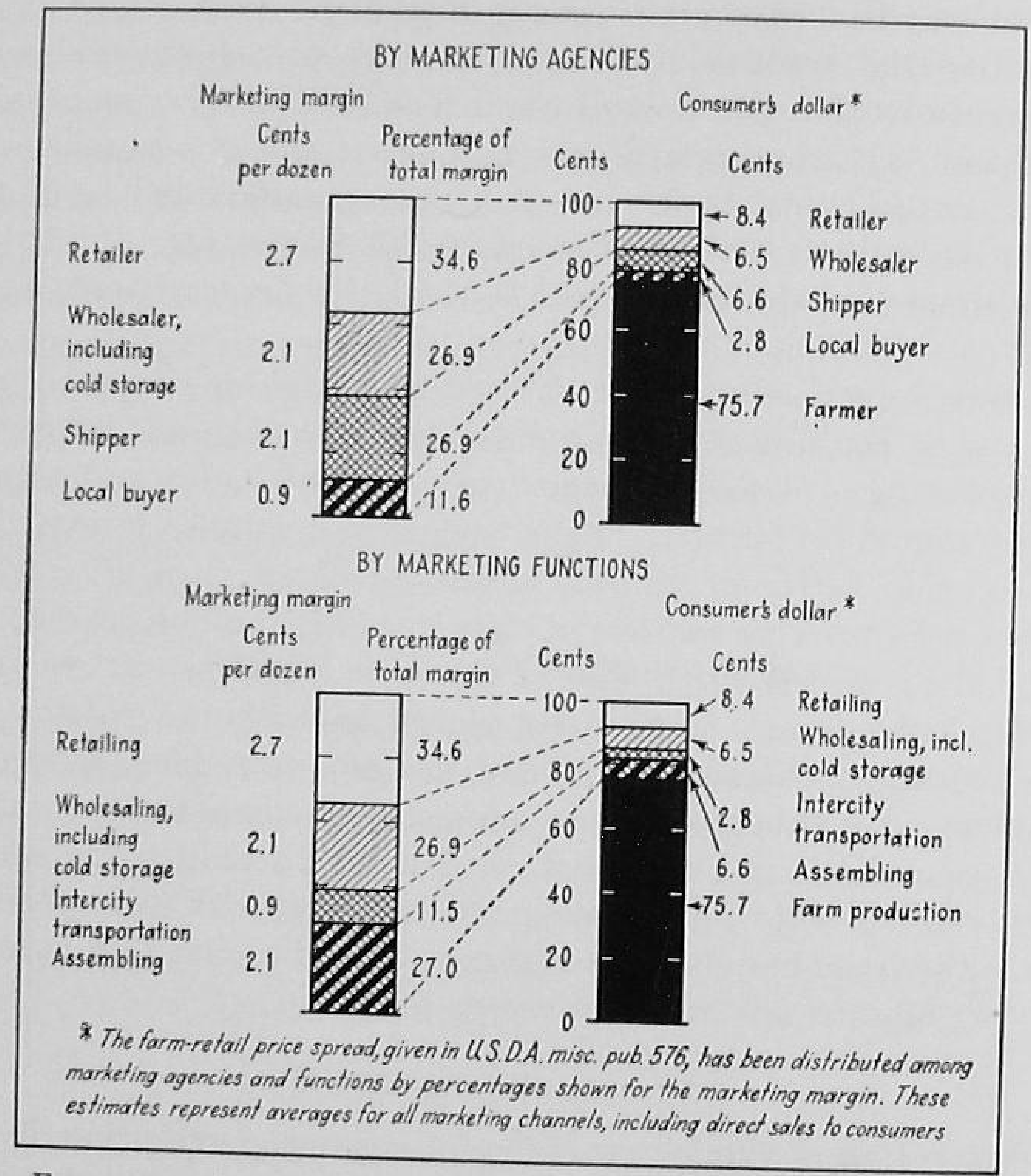


FIG. 218. Eggs: approximate distribution of the consumer's dollar, by marketing agencies and by marketing functions, United States, 1939. (*Based on official and other data and partly estimated. E. P. Winter*, 1948.)

large, however, the competitive system of marketing eggs is so keen that producers, for the most part, receive a relatively large share of the consumer's dollar paid for eggs.

The cost of marketing shell eggs, or the marketing margin, in cents per dozen is shown in Fig. 218. The marketing margin represents the differences between the farm value of eggs, or the price that producers received, and the retail price, or the price paid by consumers. In Fig. 218, the farm value was estimated on the basis of 1.03 doz. in order to allow for breakage and spoilage. It is interesting to note that the higher the farm

value and retail price of eggs, the higher in general has been the marketing margin. It is also interesting to note that since 1933, except for 1944, farmers received approximately 75 per cent of the retail price of eggs.

Data on the marketing margin and the consumer's dollar spent for eggs in the shell in 1939 are shown in Fig. 218 with respect to marketing agencies and with respect to marketing functions. In 1939 the farmer received 75.7 per cent of the consumer's dollar spent for eggs. With respect to marketing agencies, they received the following percentages of the consumer's dollar: retailer, 8.4; wholesaler, 6.5; shipper, 6.6; and local buyer, 2.8. With respect to marketing functions, the following percentages of the consumer's dollar amounted to: retailing, 8.4; wholesaling, including cold storage, 6.5; intercity transportation, 2.8; and assembling, 6.6.

For each of the following 6-year periods, the producer's share of the consumer's dollar averaged:

1913 to 1918	1921 to 1924	1925 to 1930	1931 to 1936	1937 to 1942	1943 to 1948
76	73	71	75	79	76

FACTORS AFFECTING EGG PRICES

The familiar law of supply and demand applies in establishing prices obtained for eggs, although in many cases there may be deviations from the application of this law. Its application is seen in its broadest sense

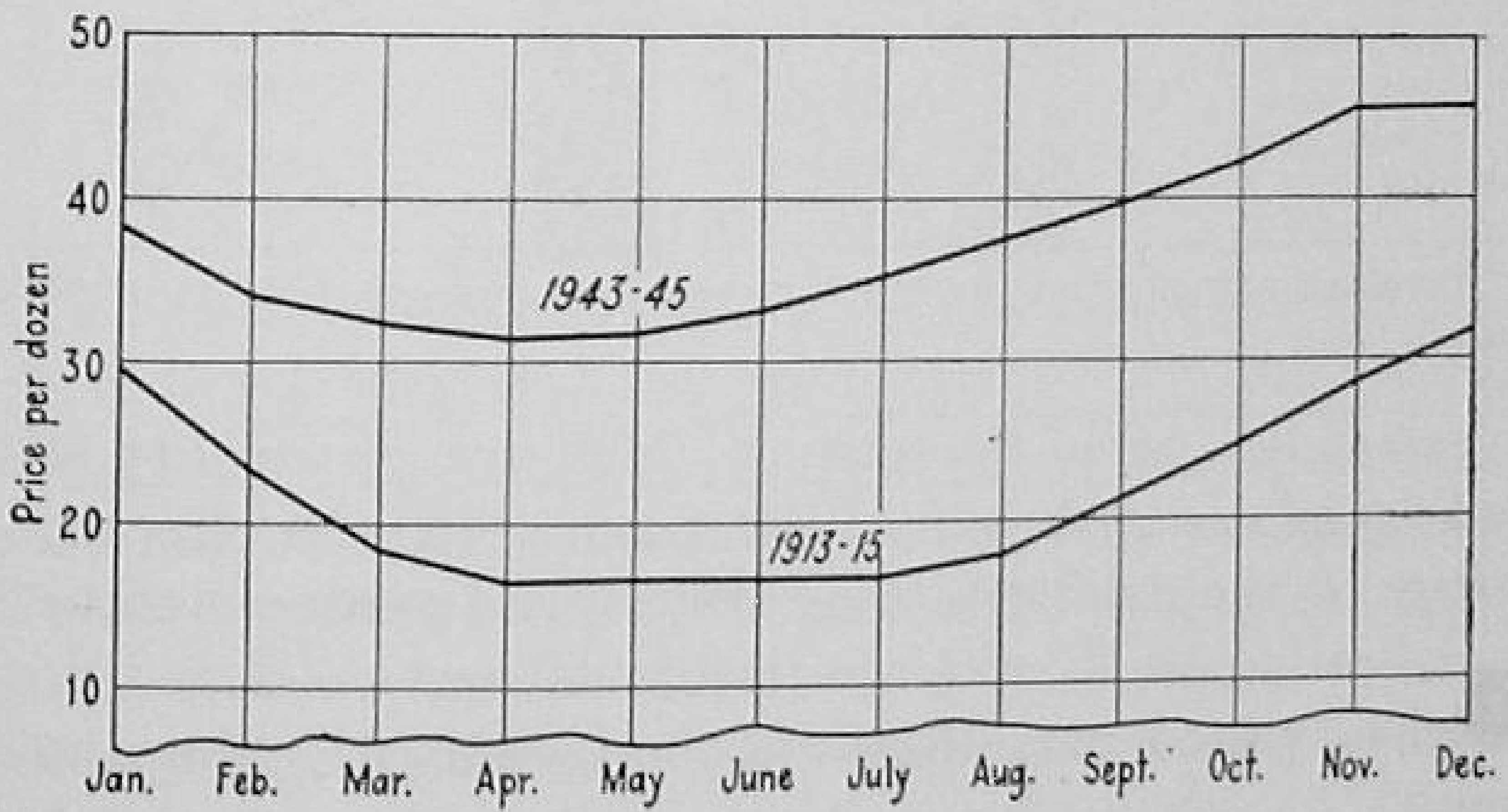


FIG. 219. Average monthly egg prices received by farmers: top line, 3-year average 1943 to 1945; bottom line, 3-year average 1913 to 1915. During recent years the relative difference between spring and fall prices has decreased as compared with former years.

with respect to the seasonal trend in egg production; high spring production is accompanied by low prices, whereas low fall production is accompanied by relatively high prices (see Fig. 219). During recent years, however, the extremes in spring and fall prices have been reduced materially as the result of many modern tendencies. Earlier hatched pullets,

the use of artificial lights to stimulate fall and early winter production, the hatching of pullets in the fall of the year, improved laying ability, better methods of feeding and housing, and holding eggs in cold storage all tend to lessen the wide range between spring and fall prices that formerly prevailed.

There is a definite seasonal trend in the demand for eggs, reaching a peak in the spring during Lent. The consumption of eggs at that time of the year is increased because of the relatively low price and probably

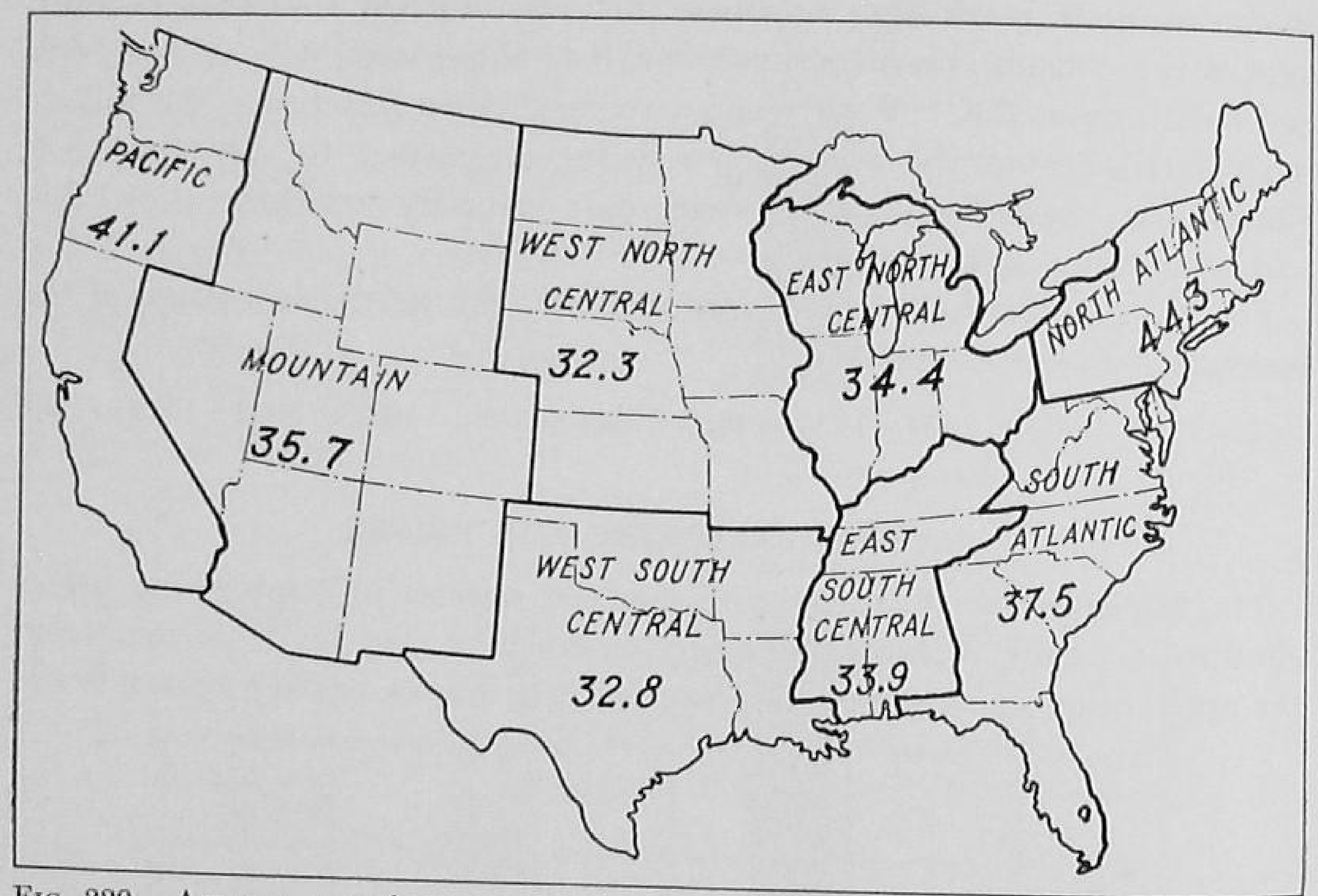


FIG. 220. Average annual price per dozen received by farmers, 1943 to 1945, according to regions.

to some extent because of the relatively high average quality of the eggs marketed. The excessive heat of the summer and the offerings of cold-storage eggs on the markets during the fall and winter months have an important bearing on the average quality of eggs marketed during this relatively long period, and, therefore, the consumptive demand for eggs is influenced.

Many other factors influence the price that producers receive and consumers pay for eggs, including the cost of grading and transporting, the "apparent" supplies, and the apparent consumptive demands. As far as the factors of apparent supply and apparent demand are concerned, it may be said briefly that certain situations arise that sometimes affect prices irrespective of the actual supply and demand of eggs. A declining market often causes a further decline which is frequently not justified

by the actual supplies available and the actual demand for eggs. Also, a rising market sometimes leads to overenthusiasm on the part of buyers, with the result that prices rise so high that further demand is affected until a subsequent reduction in price brings about a stabilized price which is in keeping with available supplies and probable demand.

The average price per dozen which producers receive for eggs varies somewhat according to the region of the country in which the eggs are produced. The Federal government publishes much data regularly pertaining to egg production and prices on the basis of eight regions, as indicated in Fig. 220. The average annual price during the 3-year period

TABLE 48. COMPARABLE VALUES IN CENTS OF GRADE A EGGS ACCORDING TO SIZE (Production and Marketing Administration, U.S.D.A., 1948)

When large Grade A eggs, with minimum weight 24 oz. per doz., cost	Medium-sized Grade A eggs, with minimum weight 21 oz. per doz., are as good or better value at	Small Grade A eggs, with minimum weight 18 oz. per doz., are as good or better value at
46 to 50	40 to 44	34 to 38
51 to 55	45 to 48	38 to 41
56 to 60	49 to 52	42 to 45
61 to 65	53 to 57	46 to 49
66 to 70	58 to 61	50 to 52
71 to 75	62 to 66	53 to 56
76 to 80	66 to 70	57 to 60
81 to 85	71 to 74	61 to 64
86 to 90	75 to 79	64 to 68
91 to 95	80 to 83	68 to 71

of 1943 to 1945 was highest in the North Atlantic region and lowest in the West Central regions.

Naturally the price per dozen is affected by the size of eggs marketed. The difference in price according to size is affected by such factors as the total volume of eggs available in relation to demand and the proportional volume of eggs of various sizes. The comparable values of eggs of different sizes but of the same quality are given in Table 48.

In some markets white eggs are quoted at a higher price than brown eggs of the same grade.

EGG-CONSUMPTION PROBLEMS

As a food product for human use, the egg is unique because its proteins, minerals, and vitamins are so important in supplying some of the deficiencies of these elements in the fruits, cereals, and vegetables which

constitute such a large part of the human diet. Fish and red meats are the principal food products that compete with eggs in supplementing the diet with proteins. In this respect, the consumption of eggs might increase if they were quoted by the pound, according to the weight per dozen, since the housewife could more readily compare the price of eggs on a pound basis with the price of fish and meat per pound.

When housewives are of the impression, during temporary periods, that egg prices are relatively high in comparison with fish and red-meat prices, the consumption of eggs is liable to suffer. During the past 30 years, however, the consumption of eggs has followed a much more even trend than have egg prices, as shown in Fig. 221. There was a slump in

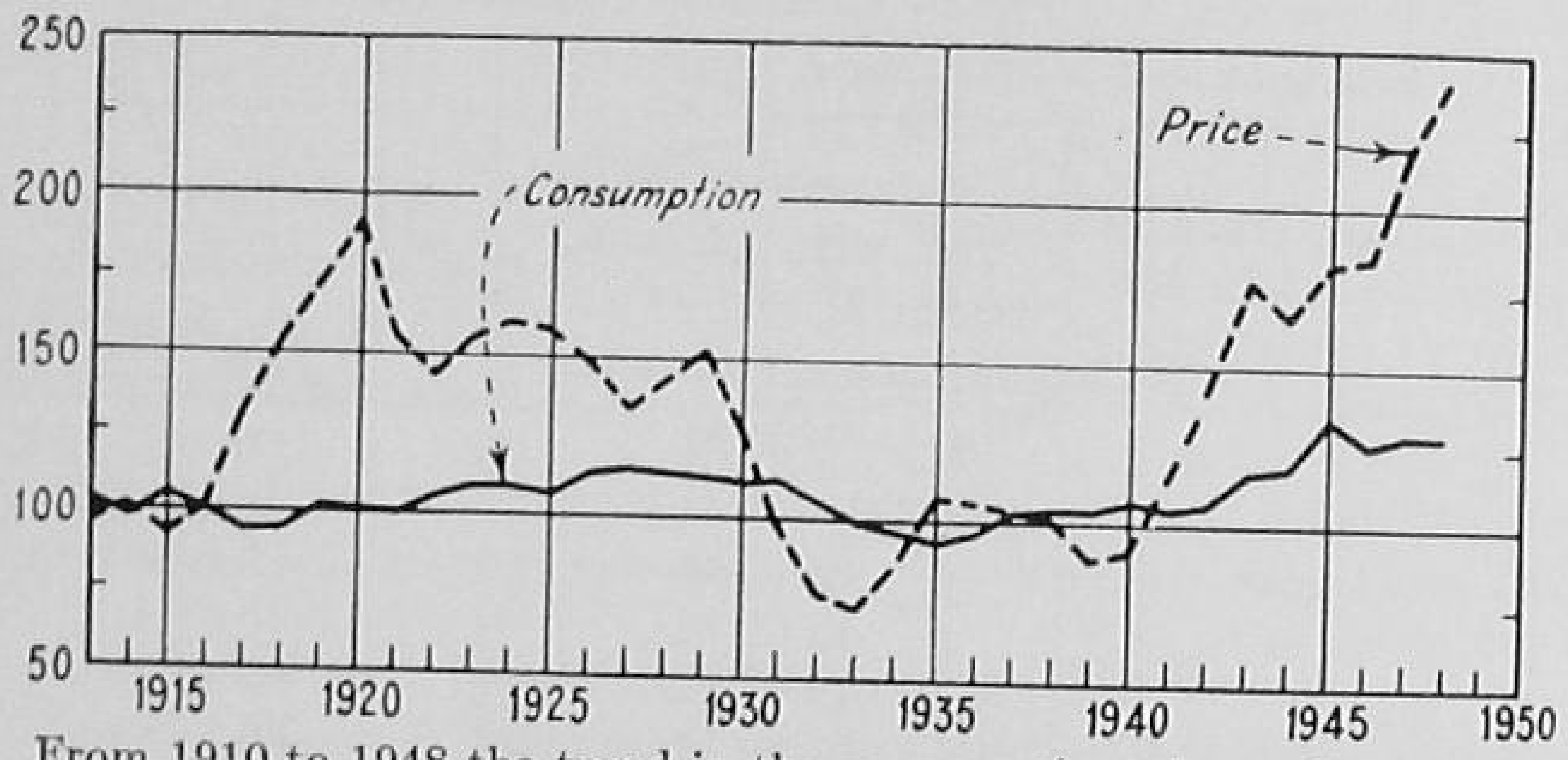


FIG. 221. From 1910 to 1948 the trend in the consumption of eggs has not been closely related to the trend in the price of eggs. (*Bur. Agr. Econ., U.S. Dept. Agr.*)

consumption during the middle thirties, following the depression. There was a marked increase in consumption during the Second World War and after.

From 1910 to the present time, the trend in per capita consumption of eggs has followed closely the trend in per capita production as shown in Fig. 222. The difference between per capita consumption and production is most accounted for by the eggs used for hatching and the wastage that normally occurs due to breakage and spoilage. With respect to Fig. 222, it should be pointed out that during the Second World War considerable quantities of dried eggs were shipped overseas to the members of the armed forces and to Great Britain.

Except for the middle thirties, the per capita consumption of eggs has shown a tendency to increase, as shown by the following figures based on 3-year averages:

1914 to 1916	1924 to 1926	1934 to 1936	1944 to 1946
302	327	317	374

The future demand for eggs will not only depend on per capita consumption but also on the rate of increase in the human population. A

marked increase in the average quality of eggs sold at retail should tend to increase the demand for eggs. Other factors that will affect the future demand for eggs will be the level of employment of wage earners, the scale of wages, and the price of food products that most directly compete with eggs for the consumer's dollar.

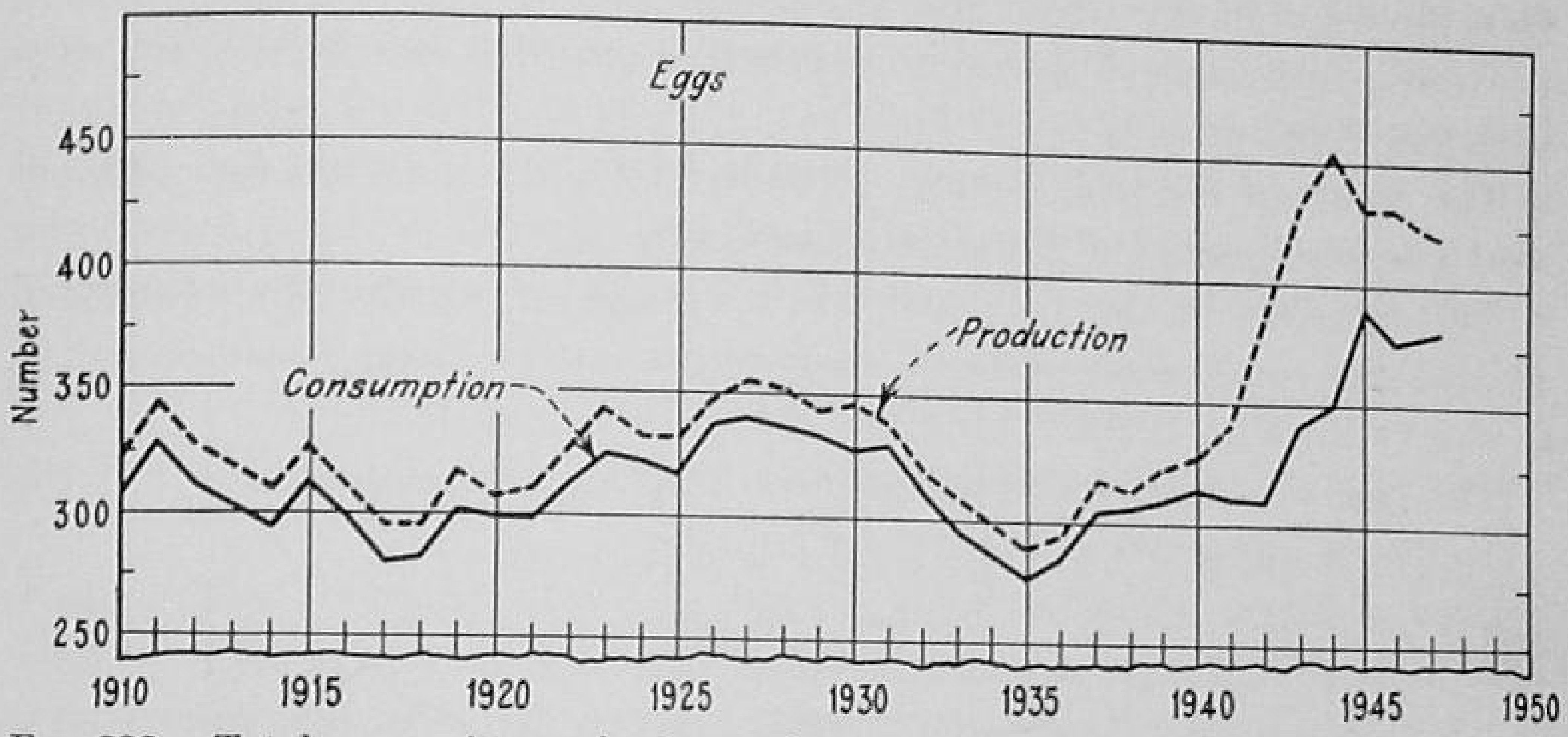


FIG. 222. Total per capita production and consumption of eggs, United States, 1910 to 1947. The consumption during 1941 to 1945 (Second World War) applies to civilian consumption only.

Food Value of Eggs. The egg is composed largely of proteins and lipids (fatty substances), two of the most important dietary essentials. The egg is a poor source of carbohydrates, which, however, are in abundant supply in fruits, cereals, and vegetables. The egg contains various

TABLE 49. CHEMICAL COMPOSITION IN PER CENT OF CHICKEN EGGS, VITAMINS NOT INCLUDED
(Alexis L. and Anastasia J. Romanoff, 1949)

	Egg with shell	Yolk and white	Yolk	White
Water	65.6	73.6	48.7	87.9
Protein	12.1	12.8	16.6	10.6
Lipids	10.5	11.8	32.6	0.03
Carbohydrates	0.9	1.0	1.0	0.9
Minerals	10.9	0.8	1.1	0.6

minerals and nearly all the known vitamins, with A, D, thiamine, and riboflavin being present in important amounts. The chemical composition of eggs is given in Table 49.

The shell of the egg is comprised of 98 per cent calcium, plus phosphorus, magnesium salts, traces of iron, sulfur, and a few other minerals.

The proteins of the yolk are ovovitellin and ovolivetin in the proportion of 4 of the former to 1 of the latter. Ovovitellin contains approximately one-third of the phosphorus content of the yolk, and ovolivetin contains approximately one-third of the sulfur content of the yolk. The proteins of the white with the percentage that each contributes of the total proteins in the white are: ovalbumin, 75 per cent; ovamucoid, 13 per cent; ovamucin, 7 per cent; ovoconalbumin, 3 per cent, and ovoglobulin, 2 per cent.

The lipids of the yolk consist of about 62 per cent true fats, 33 per cent phospholipids, and 5 per cent sterols.

The minerals in the yolk and white consist of organically combined phosphorus, potassium, sodium, magnesium, sulfur, iron (practically all in the yolk), zinc, copper, bromine, manganese, and iodine.

The egg is a highly digestible food product, the digestibility of the white being improved somewhat by cooking.

Uses of Eggs. Besides being served as fried, poached, soft cooked, and in omelets, croquettes, and soufflés, eggs are used in a great variety of ways to improve the nutritive value, flavor, texture, and appearance of many other food products.

Frozen and dried eggs are used to enrich bread, cakes, and pie fillings and in the manufacture of many kinds of bakery products, candies, confections, ice cream, mayonnaise, noodles, macaroni, salad dressing, prepared flours and puddings, and numerous other products.

Imports and Exports. The United States import and export trade in eggs and egg products has been of relatively slight importance. From 1920 to 1930 the imports of shell eggs and egg products, in terms of total shell-egg equivalent, varied from about 40 to about 80 million doz. During the same period, the exports of shell eggs and egg products, in terms of shell-egg equivalent, varied from about 12 million to 34 million doz. Since 1931, except for exports during the Second World War amounting to a little over 10 per cent of the total production, imports and exports of eggs and egg products have been very limited.

ANIMAL-FOOD AND TECHNICAL USES OF EGGS

Inedible eggs and infertile eggs and dead embryos in the hatchery industry are utilized for making dog, fox, and mink food. On some farms they are fed to hogs or used as fertilizer. Eggshells, as a by-product of egg-breaking plants, are sometimes crushed and incorporated in poultry mashes.

The technical uses to which eggs are put are many, although the total volume of eggs involved is relatively small. The oil of egg yolk is used in making certain emulsions and ointments. The white of the egg is slightly germicidal and is sometimes used as an antidote for certain

poisons. Considerable quantities of egg white are used in the preparation of culture media. Artificial-insemination diluents used in dairy-breeding work usually contain egg yolk.

In the early stages of development, chicken embryos serve as excellent material for the culture of various bacteria and viruses. Fertile eggs are used extensively in the production of immunizing serums and vaccines against animal diseases, including some affecting humans.

Very small quantities of eggs are used in making artists' paints, as fixing agents in the manufacture of dyes, and for other purposes such as cementing cork to bottle caps, leather tanning, photography, gilding books, and textile printing.

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CHAPTER 13

MARKETING POULTRY

Problems pertaining to the marketing of poultry are of interest to producers because the net income from poultry meat sold is involved. Selling poultry alive is the simplest and easiest method, but in many cases it is more profitable to sell poultry partially or completely prepared (ready-to-cook) for consumer use. Most farmers and many commercial-poultry producers, of course, are obliged to sell practically all their poultry alive. On the other hand, increasing numbers of poultry raisers make use of mechanical equipment in killing and plucking poultry and preparing it for sale direct to consumers, stores, and institutions.

Poultry producers are naturally anxious to secure the highest possible price for the birds they sell. Many producers, however, are unmindful of the factors which tend to lower the price they receive for their poultry. Such factors as including sick birds in the lot offered for sale, great variation in size and body conformation, and poorly fleshed birds all tend to lower the price paid to producers. If dressed or drawn poultry is being sold, poor bleeding, torn skin, pinfeathers, and other imperfections tend to lower the price. On the other hand, poultry buyers could do much to encourage the production of poultry of superior quality if all their purchases were made on the basis of grade and quality.

Except for the fact that birds weighing less than 1.5 lb. are rarely sold for consumption, market poultry includes growing birds of various ages and weights, pullets and hens culled from the laying flocks, and old breeding hens and roosters. Consumers, for the most part, prefer birds with yellow skin to those with white skin. Poultry buyers often discriminate against birds with feathered shanks and those with black plumage because the latter are apt to have numerous dark pinfeathers when dressed for market. General-purpose breeds are usually preferred to Leghorns by poultry buyers.

CLASSES OF AND STANDARDS OF QUALITY FOR POULTRY

Poultry-dressing plants are located in all parts of the country, including those in the principal poultry-producing areas and those in numerous large cities. Since most farmers and commercial-poultry raisers do not have a ready market for dressed, eviscerated, or cut-up chickens, most of

the broilers, fryers, roasters, and hens are sold alive. They are taken to commercial dressing plants in trucks or are shipped by rail.

Dressing plants located in the producing areas serve to reduce the cost of shipping poultry to the consuming centers, since it costs less to ship dressed, eviscerated, and cut-up chickens than live birds. Also, the costs of operating dressing plants in the country are less than in cities. If it were not for the demand of the Jewish trade for live chickens, practically all birds would be prepared for consumer use in country dressing plants. When evisceration is done in country dressing plants, it is possible to make commercial use of the large quantities of heads, feet and shanks, and inedible viscera.

Classes of Live Poultry. In order to facilitate the pricing and marketing of live poultry according to class and quality, different classes of poultry are recognized by poultry-marketing interests.

Broiler or Fryer. A broiler or fryer is a chicken of either sex, usually under 16 weeks of age, that is tender-meated with soft, pliable, smooth-textured skin and flexible breastbone cartilage.

Roaster. A roaster is a chicken of either sex, usually under 8 months of age, that is tender-meated with soft, pliable, smooth-textured skin and breastbone cartilage that is somewhat less flexible than that of a broiler or fryer.

Capon. A capon is a castrated male chicken, usually under 10 months of age, that is tender-meated with soft, pliable, smooth-textured skin.

Stag. A stag is a male chicken, usually under 10 months of age, with coarse skin, somewhat toughened and darkened flesh, considerable hardening of the breastbone cartilage, and some spur development.

Hen or Stewing Chicken or Fowl. A hen or stewing chicken or fowl is a mature female chicken, usually more than 10 months old, with meat less tender than that of a roaster, and nonflexible breastbone.

Cock or Old Rooster. A cock or old rooster is a mature male chicken with coarse skin, toughened and darkened meat, hardened breastbone and usually well-developed spurs.

Live-poultry Standards of Quality. The U.S. Department of Agriculture has promulgated standards of quality for live poultry belonging to the various classes mentioned above. The following factors are considered in ascertaining the quality of an individual bird: (1) health and vigor, (2) feathering, (3) conformation, (4) fleshing, (5) fat underlying the skin, and (6) freedom from defects.

Three standards of quality are recognized: (1) A Quality or No. 1 Quality, (2) B Quality or No. 2 Quality, (3) C Quality or No. 3 Quality. Conformation and fleshing are the most important factors that determine differences among A, B, and C Quality birds.

Detailed specifications of quality grades for live poultry may be secured by writing the U.S. Department of Agriculture at Washington, D.C.

Dressed and Eviscerated or Ready-to-cook Standards of Quality. The U.S. Department of Agriculture has promulgated standards of quality for dressed and eviscerated or ready-to-cook poultry on the basis of the following factors: (1) conformation, (2) fleshing, (3) fat underlying the skin, (4) freedom from pinfeathers, (5) freedom from bruised and torn skin, (6) freedom from broken bones, and (7) freedom from other defects.

Three standards of quality are recognized: (1) A Quality, (2) B Quality, and (3) C Quality. Conformation, fleshing, and freedom from various defects are the most important factors that determine differences among A, B, and C Quality birds.

Detailed specifications of quality grades for dressed and ready-to-cook poultry may be secured by writing to the U.S. Department of Agriculture at Washington, D.C.

PREPARING POULTRY FOR CONSUMPTION

The first steps in preparing poultry for consumption include killing by bleeding and plucking the feathers or dressing. Birds thus prepared for market were long known as "New York dressed" but are now called "dressed." Heads and shanks and feet are removed, and the dressed poultry is then drawn or eviscerated, which consists of removing the viscera. Sometimes a distinction is made between drawn and eviscerated birds, the latter also having the lungs and oil sac removed. The edible viscera consist of the heart, liver, kidneys, and gizzard, and the inedible viscera consist of the windpipe, lungs, spleen, gall bladder, and the entire intestinal tract.

Young chickens are frequently further prepared for consumer use by cutting each bird into halves for broiling or into parts for frying, in the latter case the popular market being "cut-up chicken." Still another way of preparing birds weighing about 2 lb. dressed weight is to divide each bird into two equal parts, and from each half all the bones are removed except the thighbone, around which the white and dark meat is wrapped, the finished product being called "poulet mignon."

Other forms in which poultry is prepared for consumer use include canned whole chicken, half chicken in jelly, white meat in jelly, and boneless chicken. Special preparations containing chicken meat in some form include canned chicken soup, chicken and egg noodles, and chicken chow mein. Chicken livers are often sold separately, also combs, testes,

feet, and fat, the last of which is in demand for use in the Jewish bakery trade.

The various processes outlined in the following discussion in preparing poultry for consumption apply in the case of birds killed and dressed on the producers' premises as well as in poultry-dressing plants, although the facilities available may vary greatly.

Farmers and commercial-poultry producers living near towns and cities are often in a position to take advantage of good market outlets for dressed, eviscerated or ready-to-cook and cut-up chicken, especially

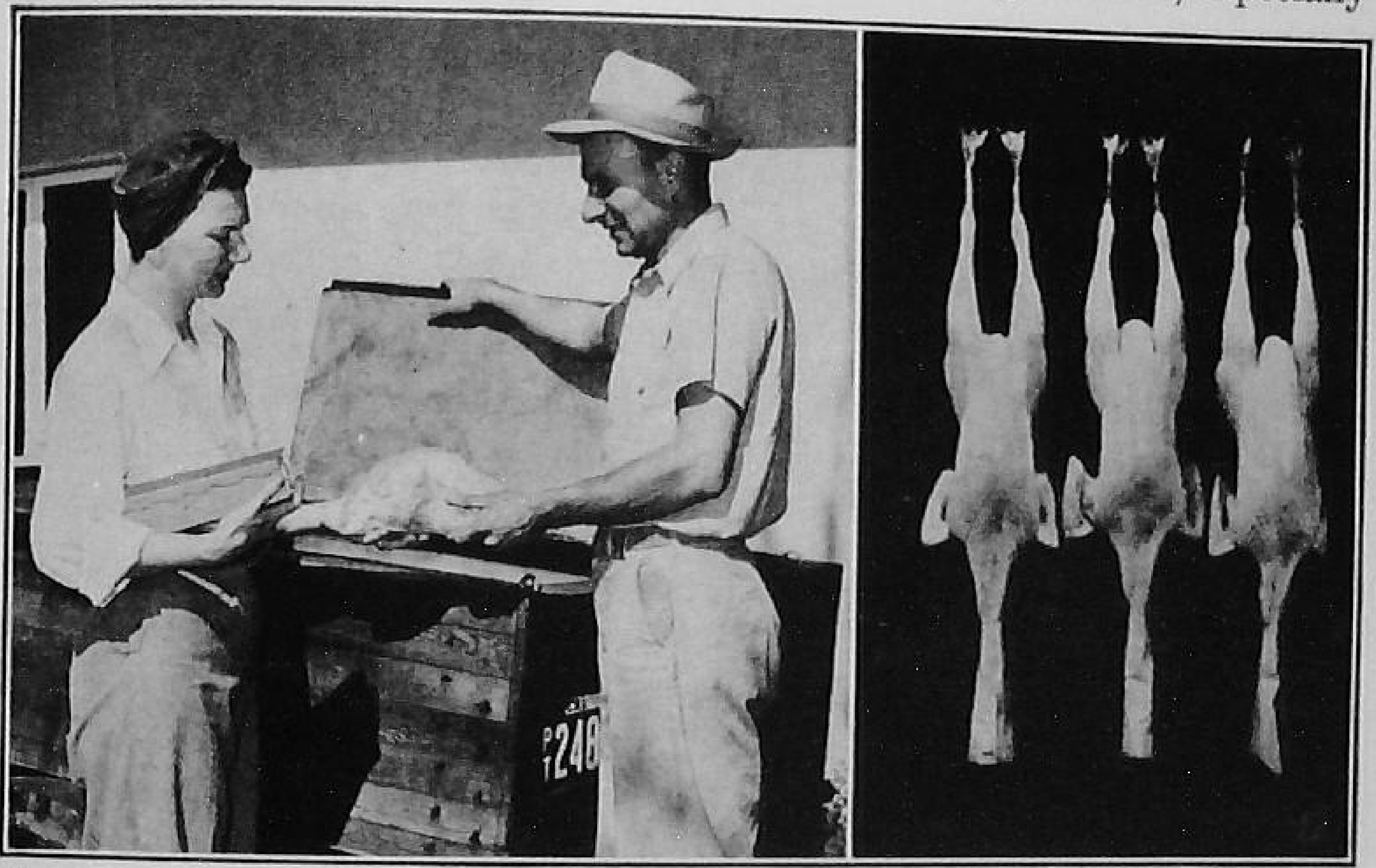

Fig. 223. Left, Messrs. Donica and Ferguson, who operate the Donson Poultry Farm in California, use a refrigerated trailer truck to deliver fresh-killed poultry to their customers every week. (*R. Hartman, Pacific Poultryman.*) Right, roasters such as these, excelling in conformation and fleshing, give complete consumer satisfaction. (*W. A. Maw.*)

if they already have an egg route. Since culling the laying flock is practiced regularly at certain seasons of the year, some farmers find it advantageous to sell these birds dressed or eviscerated rather than alive. Also, it is possible in many cases to develop a good trade in dressed and eviscerated poultry with stores, hotels, and hospitals.

Among 184 farmers in the State of New York who sold dressed and eviscerated birds during the period from July 1, 1946, to June 30, 1947, it was determined that they received about the same labor returns as caring for laying flocks and about twice as much as for raising chickens. Pertinent data on costs, profits, and returns per pound of chicken and returns per hour of labor are given in Table 50.

Fasting Before Killing. In order that the crops of birds may be relatively free of feed material when killed for market, the birds should be

fasted for about 3 or 4 hr. prior to being killed. This applies to birds fed mash mixtures exclusively, as in the case of birds killed in commercial-poultry-dressing plants. Farm-raised birds fed whole grains exclusively

TABLE 50. COSTS, PROFITS, AND RETURNS PER POUND OF DRESSED AND EVISCERATED POULTRY AND RETURNS PER HOUR OF LABOR, 184 FARMS IN NEW YORK, 1946 TO 1947
(E. N. Searls, 1948)

Item	Dressed	Eviscerated
Operating costs, cents per lb	6.2	7.5
Cost of live birds, cents per lb	35.3	36.8
Total costs, cents per lb	41.5	44.3
Returns for custom work and offal, cents per lb	0.3	0.3
Returns for birds sold and eaten, cents per lb	43.9	45.8
Total costs, cents per lb	44.2	46.1
Profit per lb., cents	2.7	1.8
Returns per lb., cents	38.0	38.6
Returns per hour of labor, dollars	1.14	0.88

or whole grains and mash should be fasted for about 7 or 8 hr. before being killed on the premises. During the fasting period, the birds should be given water.

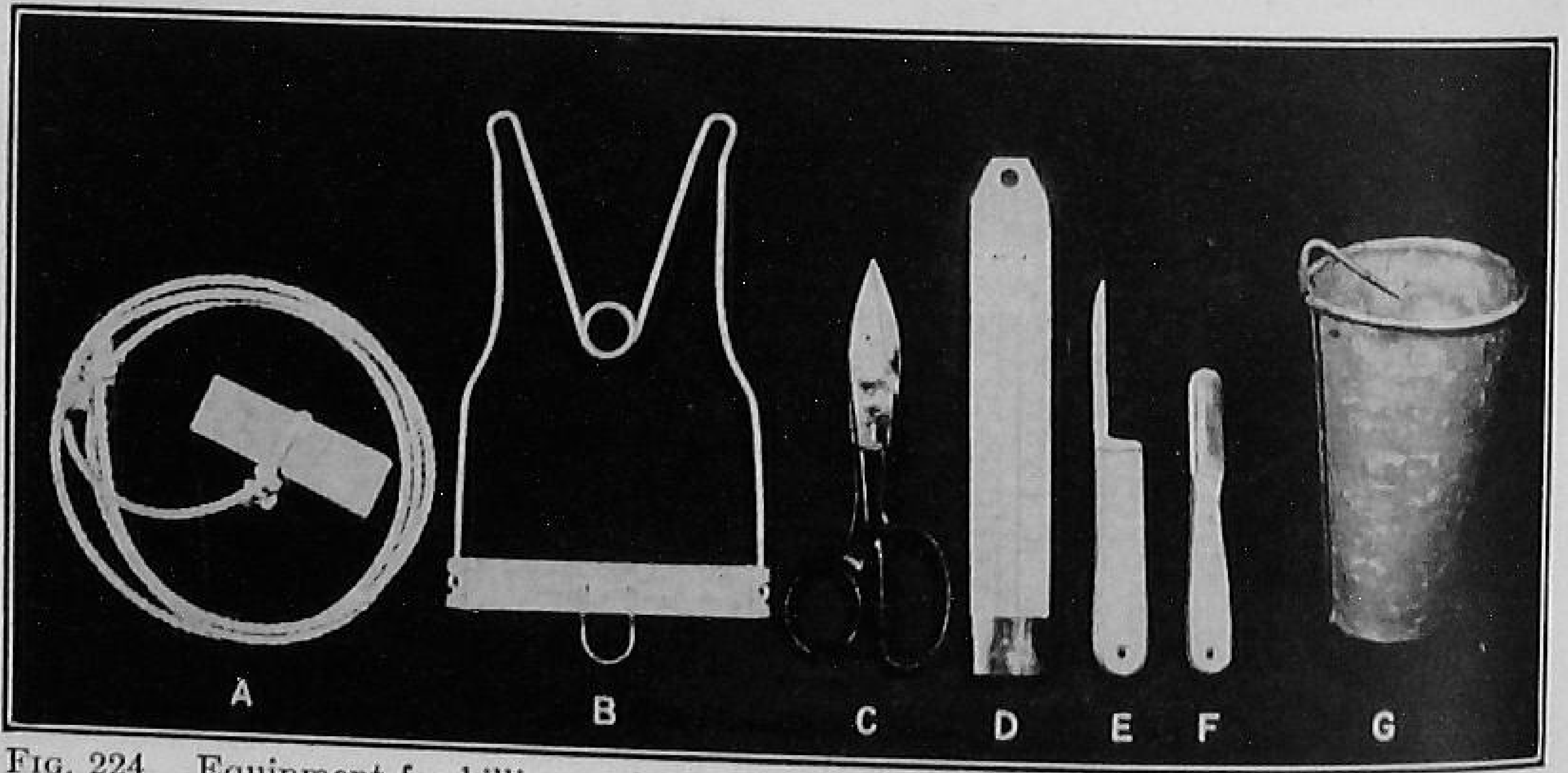

FIG. 224. Equipment for killing and dressing poultry at home. From left to right: rope and block for suspending birds, shackle, scissors for removing heads and feet and shanks, thermometer, sticking knife, pinning knife, and blood cup. (*F. Z. Beanblossom and R. W. Snyder*, 1947.)

Killing by Bleeding. The conventional method of killing birds is by causing them to bleed to death, which is accomplished by severing the large blood vessels of the neck just back of the head. Decapitation and dislocation of the neck are two common methods which producers have

employed when killing birds for home use. Severing the brain to cause loosening of the feathers, by inserting a sharp knife through the mouth and then cutting the blood vessels from the inside, is a method frequently employed in killing birds at home and in commercial dressing plants, especially for dry plucking. An electric killing knife is on the market that produces an electric shock in the brain when the blood vessels are severed. Since in commercial practice practically all poultry is scalded in order to save time and make plucking easier, the blood vessels are severed by cutting the throat from the outside. This method is employed in most poultry-dressing plants.

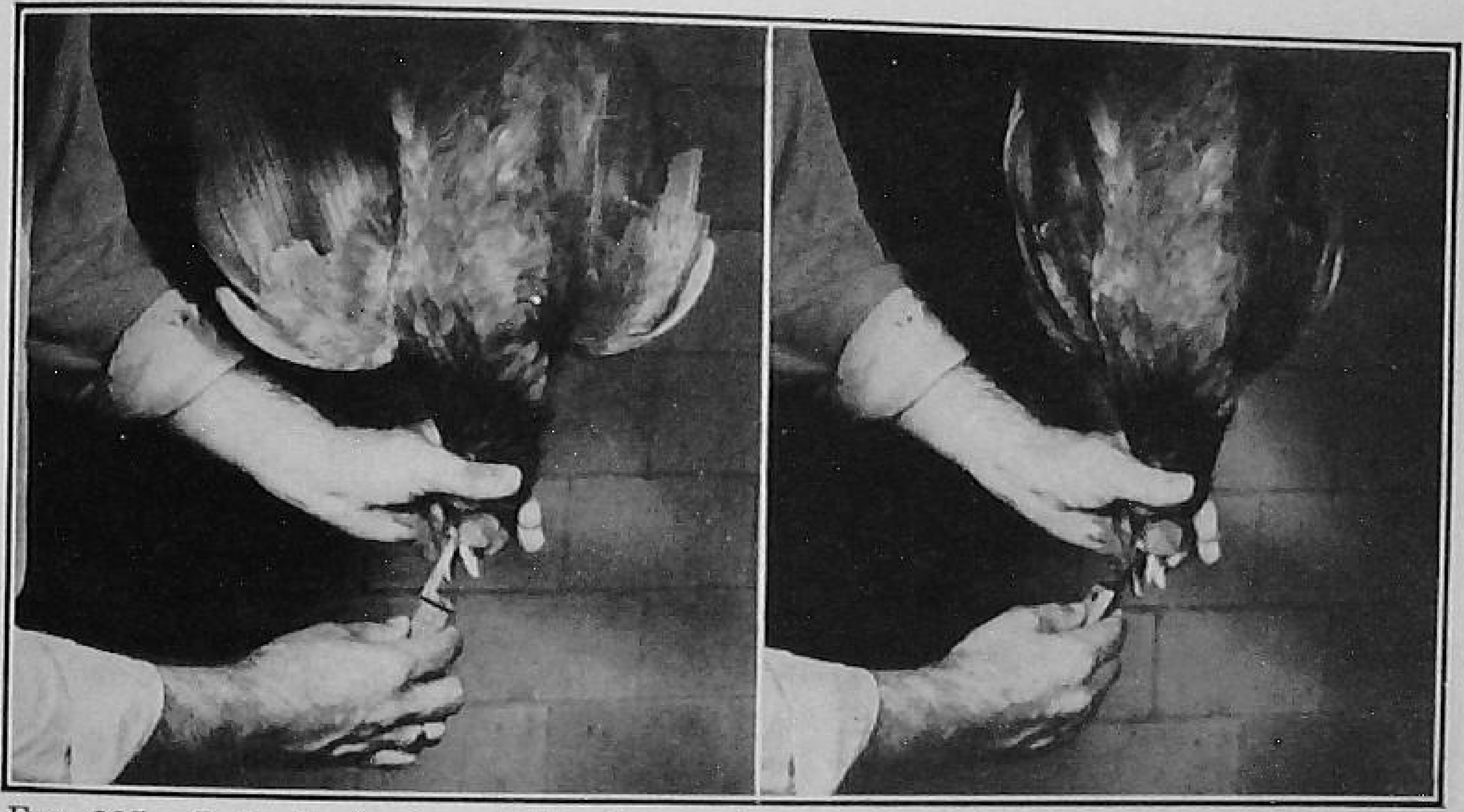

FIG. 225. Left, beginning of bleeding process, cutting edge of knife away from blood vessels. Right, finish of bleeding process, cutting edge of knife toward blood vessels. (*F. Z. Beanblossom and R. W. Snyder*, 1947.)

Poultry killed for the orthodox Jewish trade must be slaughtered under the supervision of a rabbi, such poultry being known as "kosher killed." One of the essential features in kosher killing is that the blood vessels, esophagus, and trachea or windpipe must be severed. After the bird's throat has been cut, the bleeder must pass his thumb forward from the rear of the neck to push out the end of the trachea to make sure that it has been completely severed.

In commercial dressing plants the birds are usually suspended head downward from shackles, the wings of the birds being about on a level with the elbows of the bleeder. For killing birds at home, a convenient method is to insert them head downward in funnels with their heads protruding below the opening at the base of the funnel. A blood cup may be attached to the mouth of each bird to catch the blood while the bird is being plucked.

Blood Loss in Bleeding. The volume of blood in the body of growing chickens of both sexes is practically the same and amounts to about 10 per cent of the body weight. After females attain sexual maturity, the volume of blood in the body does not increase in proportion to the increase in body weight because the gradually accumulating fat in the body contains little blood. On the other hand, the volume of blood in the body of males increases in proportion to the increase in body weight up to about 9 lb. In the killing operation, chickens lose between 35 and 50 per cent of the blood in the body. Kosher-killed birds and those that are debrained and stuck lose relatively more of their total volume of blood than birds that are decapitated.

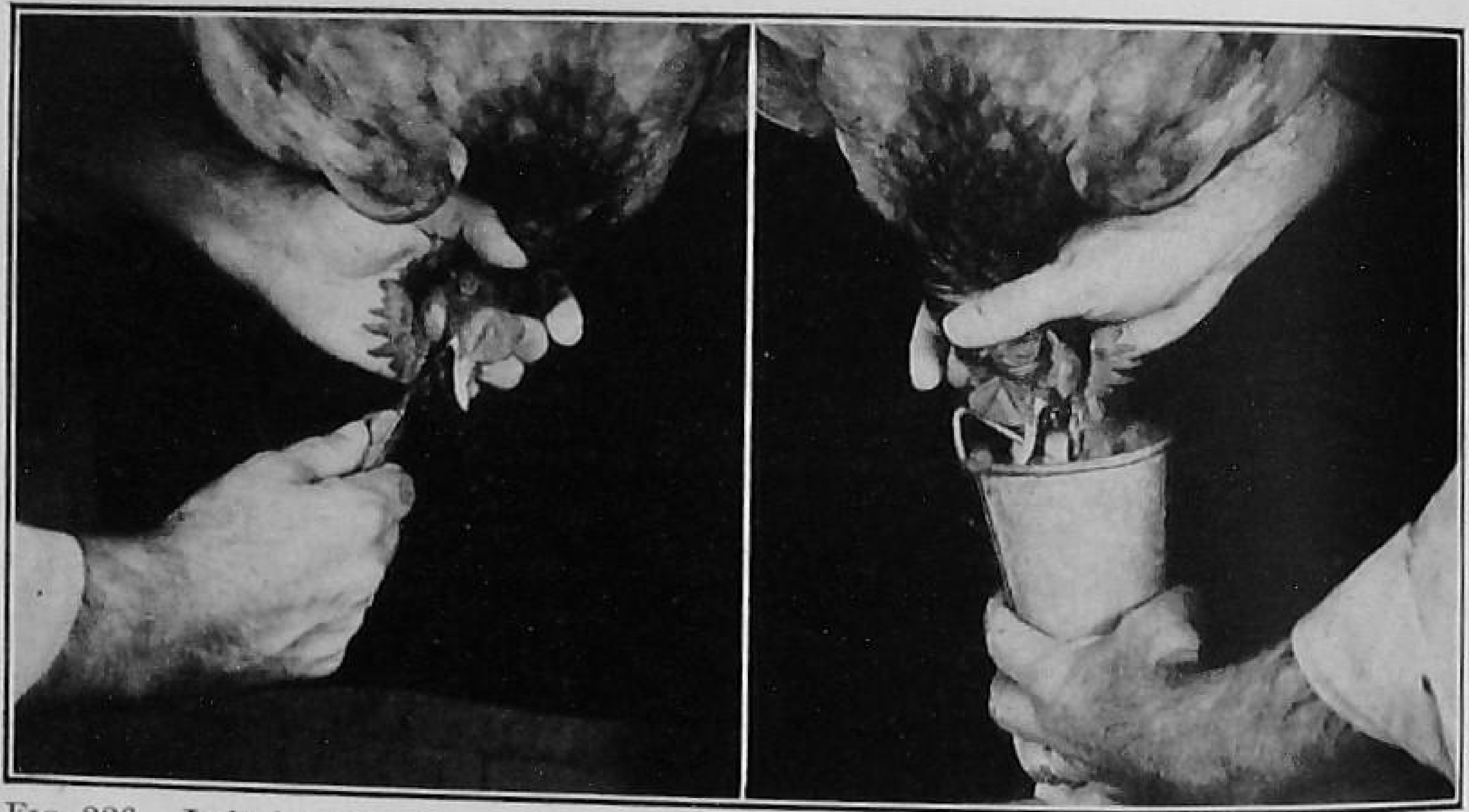

Fig. 226. Left, braining through eye socket. Right, attaching blood cup. (*F. Z. Beanblossom and R. W. Snyder*, 1947.)

Improper bleeding results in objectionable-looking dressed poultry, as evidenced by blood being present in the feather follicles on the neck, hips, thighs, and wings. Sometimes birds swallow blood that causes a discoloration of the crop.

Plucking. Dry plucking, so generally practiced years ago, has almost entirely given way to plucking after the bird has been immersed in scalding water. Dry-plucking machines, commonly used in England and Europe, have not been used in this country to any extent.

Hard Scalding. The hard-scalding method of plucking involves immersing each bird in water ranging in temperature from 180 to 190°F. The time of immersion varies with the temperature of the water but in all cases should be only long enough to ensure easy plucking and not long enough to make parts of the skin, especially over the legs, look parched after the dressed birds are cooled.

Subscalding. In processing poultry that is to be quick-frozen and sold as ready-to-cook or cut-up chicken, the water in which the birds are immersed should not be over 140°F. This method reduces labor in removing pinfeathers and lightens the color of the skin.

Semiscalding. The semiscalding or slack-scalding method of plucking involves immersing each bird in water or spraying it with water ranging in temperature from 122 to 128°F. for about 30 sec. The proper temperature of the water for broilers is about 127 or 128°F., depending upon their size, and for roasters about 130°F. In some commercial dressing

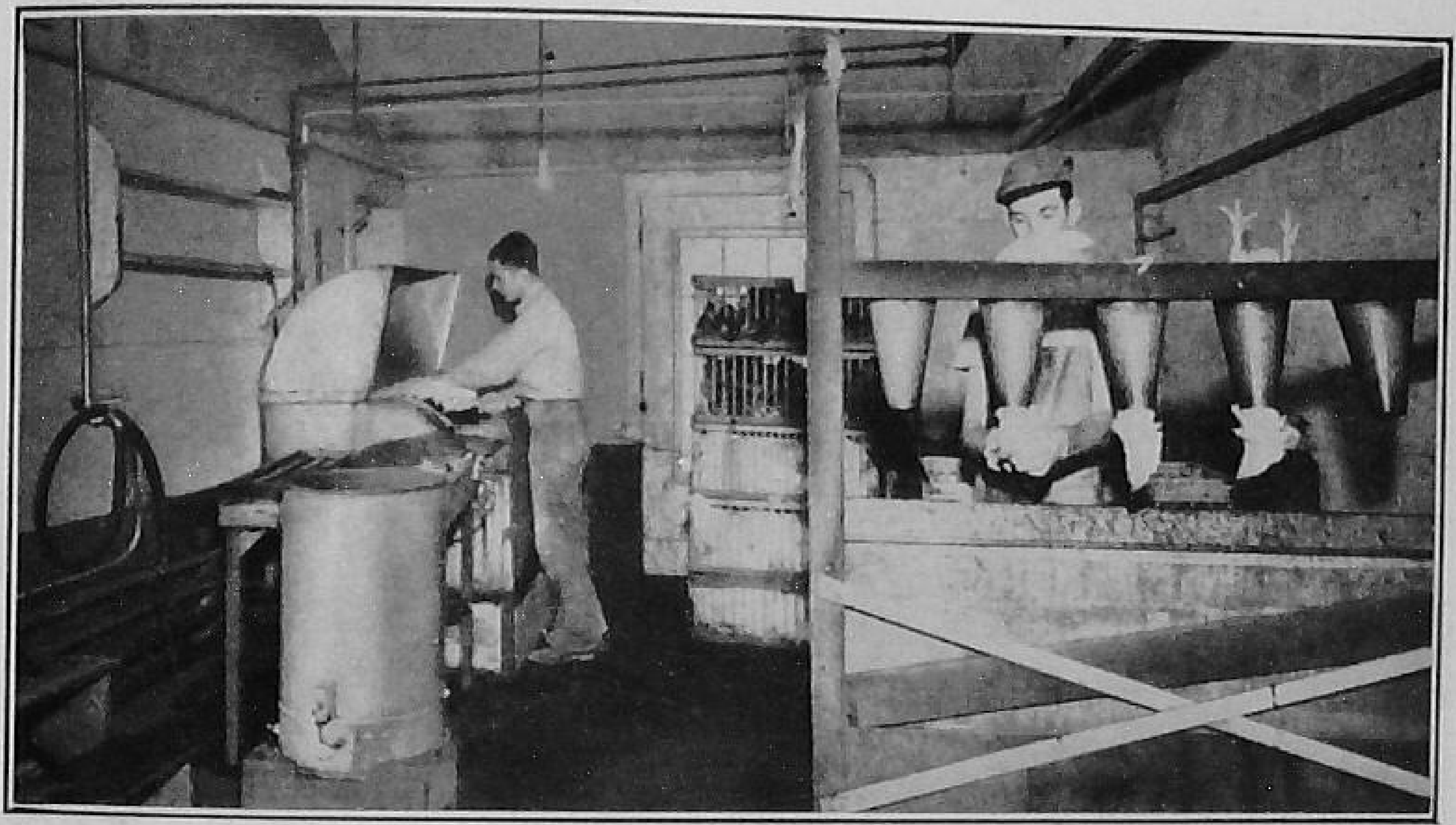

FIG. 227. Killing and dressing room at Linwood Farms in the State of New York showing chickens being bled while held in funnels, a scalding tank, and a chicken being plucked with an automatic plucking machine. (*Photograph by J. C. Scholes, Beacon Milling Company.*)

plants, lower temperatures are used and the period of immersion or spraying is longer, in some cases up to 90 sec. A wetting agent added to the water increases its surface tension and tends to make plucking easier. Spraying is much more sanitary than immersion because in the latter case every additional bird that is immersed increases the number of bacteria in the water. If the birds are immersed in water, it should be changed frequently to keep bacterial contamination at a minimum.

Plucking is started immediately following semiscalding. When dressing is done on the producers' premises, the birds should be hung from shackles or may be plucked by using a mechanical plucking machine equipped with rubber "fingers" or buffers. In commercial dressing plants the birds are moved from the scalding equipment to automatic plucking machines while hanging from shackles suspended from an endless motor-driven track or conveyor. In many plants different types of

Fig. 228. Showing arrangement of killing, dressing, and cooling equipment to save steps. (*Gordon Johnson Company.*)

Fig. 229. Removing wax coating from birds in a commercial dressing plant. (*Birds Eye-Snider, Inc.*)

machines are used for plucking feathers from different parts of the body. After the feathers have been removed, the birds are moved along by the endless conveyor to a section of the plant where pinfeathers are removed by "pinners" who use dull, short-bladed pinning knives.

Waxing. An additional step in the semiscald method of plucking just discussed consists of dipping the birds in molten wax after most of the feathers have been plucked. Before being dipped in the molten wax, the heads of the birds are fastened in the shackles along with the feet so that the neck, body and legs, except the shanks, pass through the molten wax. Either one or two tanks of wax are used in commercial-dressing

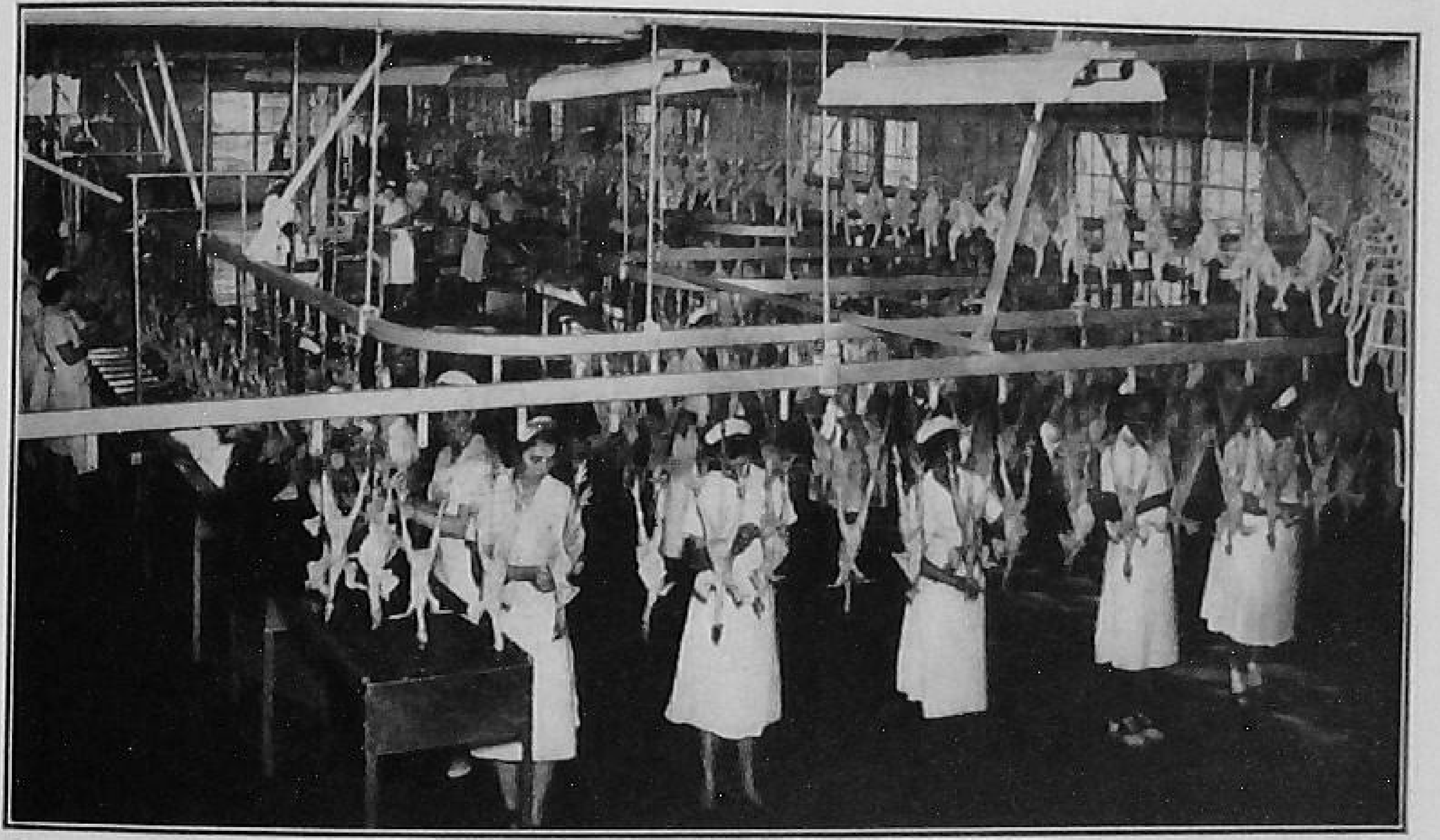

FIG. 230. An important factor in dressing poultry commercially is the removal of pinfeathers. (*Photograph courtesy of The Salisbury Times.*)

plants. When two tanks are used, the temperature of the wax in the first tank is kept as high as 160°F. and in the second tank at a temperature of from 128 to 138°F. The birds spend only about 3 sec. in the first tank and receive a thin coating of wax, and the second tank is spaced at a sufficient distance from the first tank so that the thin coating of first-tank wax becomes sufficiently cooled so that the thicker coating of second-tank wax adheres firmly.

From the second tank of wax the birds are dipped, while still suspended from the shackles, in a tank of cold water or are passed through a cold-water spraying chamber. This hardens the wax and makes it easy to hand peel. Removing the wax also removes dirt and any feathers that were previously not plucked, as well as practically all the pinfeathers.

In some poultry-dressing plants, a mechanical machine is used to remove about 75 per cent of the wax, the remainder being peeled off by

hand. As much as possible of the used wax is reclaimed for further use. During recent years such marked improvements have been made in automatic plucking machines that some commercial dressing plants do not practice the waxing of birds.

Singeing. All dressed poultry must have the hairs removed from the body, this being most readily done by singeing. In most modern poultry-dressing plants, automatically operated gas burners are used that completely envelop each dressed bird in flames.

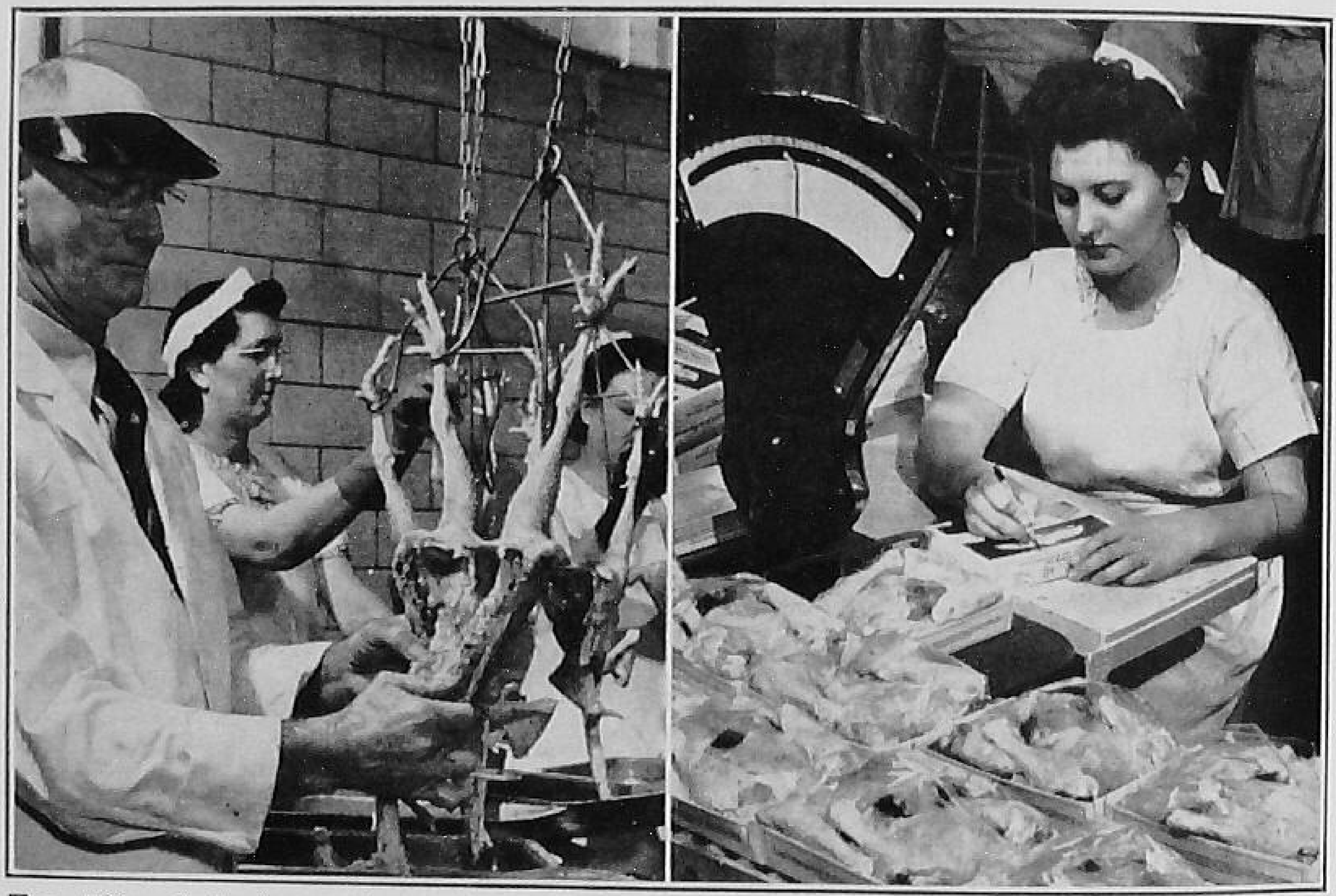

FIG. 231. Left, inspecting eviscerated birds for evidence of disease. Right, packaging cut-up chicken and weighing the cartons. (*Birds Eye-Snider, Inc.*)

Removing Feed from the Crop. Even when birds have been fasted before being killed, there is often some feed in the crop. In some dressing plants, the birds are fed a moistened mash or gruel shortly before killing time, and thus there may be considerable feed in the crop. A common practice, therefore, is to remove the feed by a downward massaging motion of the hands from the crop toward the head while the birds are still suspended from the shackles. Water is sometimes forced into the mouth to ensure the complete removal of feed. Removing feed from the crop tends to prevent fermentation from taking place, otherwise the skin over the crop is liable to become discolored and some of the flesh adjacent to the crop may become tainted.

Cleaning the Vent. The vents of many dressed birds contain fecal matter which should be removed by squeezing the vent of each bird.

This is important from the standpoint of sanitation and appearance. The presence of fecal matter may result in tainting and discoloration of the skin and flesh unless the dressed birds are cooled promptly. Also, unless the fecal matter is removed, the packages in which dressed birds are wrapped may become soiled. Plugging the vents of all birds with cotton helps a great deal in keeping the birds clean when packed and also tends to prevent the paper lining the containers in which the dressed birds are packed from becoming smeared with fecal matter.

Washing. The final stage in killing and dressing poultry is washing the birds to remove bacteria on the skin and any particles of dirt or loose pinfeathers and to improve the appearance of the birds. In commercial dressing plants the birds are usually sprayed with water, the spraying apparatus sometimes being equipped with long rubber "fingers" or buffers.

Cooling. The internal body temperature of dressed birds should be reduced to nearly 34°F. as quickly as possible after dressing operations have been completed, the internal body temperature at that time usually being about 100°F. Unless the dressed birds are thoroughly cooled as quickly as possible, bacterial decomposition sets in and the intestinal tract may cause the flesh to become tainted. "Green-struck" poultry, in which areas of the skin assume a greenish color, is the result of not thoroughly cooling the dressed birds rapidly enough to prevent bacterial decomposition. In order to determine when the desired internal body temperature has been reached during the cooling period, a thermometer should be inserted into the vent until the bulb of the thermometer is in the center of the bird.

Air Cooling. Cooling dressed birds in air is feasible on the farm when the temperature is about 32 to 34°F. Some idea of the length of time required to cool different classes of dressed birds to the required internal temperature is given in Table 51. In order that the various classes of birds that were dressed at different times would be uniform in temperature at the beginning of the experiment, they were immersed in water at a temperature of 100 to 105°F. until their internal temperature was within 2 to 4° of the temperature of the water. They were cooled in a household-type refrigerator maintained at a still-air temperature of 35°F. and a relative humidity of 70 per cent.

It was found that by circulating the air in the refrigerator at a velocity of 8.33 ft. per sec., the time required for cooling was reduced approximately one-half.

On many farms slaughtered poultry is cooled in farm freezers.

In commercial dressing plants mechanically refrigerated coolers are used accommodating portable racks of poultry, cooling temperatures

ranging from 30 to 34°F. usually being maintained. Cooling periods necessarily depend upon the size and number of birds and their body temperature at time of being placed in the cooler and the velocity of air in the cooler. Dressed poultry cooled in air usually loses from 0.5 to 2 per cent in weight.

The "cold-shock" method of cooling dressed birds has been demonstrated to be effective in reducing the cooling period as compared with air cooling. The "cold-shock" method consists of spraying the birds with brine (20 per cent sodium chloride) for from 10 to 60 min., depending upon the size of birds being cooled, and then transferring them to an air-cooling room maintained at from 32 to 35°F. and holding them there until an internal body temperature of from 34 to 36°F. was attained. Freezing brine spray shortens the cooling period as compared with non-freezing brine spray.

TABLE 51. APPROXIMATE TIME REQUIRED TO COOL DIFFERENT CLASSES OF POULTRY TO 35 AND 39°F., RESPECTIVELY, IN A REFRIGERATOR MAINTAINED AT 35°F. (I. L. Williams and E. M. Funk, 1941)

	Class of poultry					
	Broilers	Fryers	Fowl	Fowl	Fowl	Cocks
Average weight per bird, lb.	2	3	5	3	5	7
Internal temperature attained, °F.	35	35	35	39	39	39
Cooling period required, hr.	6	7.5	11.5	6.5	8.0	10.0

Water Cooling. As compared with air cooling of dressed poultry, water cooling results in plumper birds with the skin having a "bloom" more nearly like that of dry-plucked birds. Immersing dressed birds in cold water is a convenient method of cooling on the farm and in commercial dressing plants. Metal containers for cooling dressed birds killed at home and metal vats for cooling dressed birds in dressing plants are more sanitary than wooden containers or concrete vats. The rate of cooling the birds is accelerated if cracked or crushed ice is added to the water.

In commercial dressing plants, the rate of cooling is further accelerated by admitting air under pressure at the bottom of the tanks in order to keep the ice and water agitated. The cooling tanks should be equipped with overflow valves so that the water is changed about every ½ hr., otherwise bacterial contamination increases to a dangerous level. Since additional batches of dressed birds added to the cooling tanks increases the number of bacteria, the tanks should be cleaned at intervals with a hypochlorite solution or with one of the quaternary ammonium com-

pounds. Agitating the ice and water by air under pressure cools dressed birds sufficiently in about 4 hr., and the birds increase up to about 2 per cent over the original dressed weight.

Eviscerating Dressed Birds. On producers' premises and in poultry-dressing plants, dressed birds are either drawn or eviscerated. Dressed birds sold by the pound in butcher shops and stores are usually drawn for the convenience of the purchaser.

The removal of the viscera from drawn birds reduces the likelihood of odors and flavors being absorbed by the flesh from the intestinal tract. Tests have shown that in order to retain the desirable aroma and flavor of poultry meat, two of the best methods to follow are: (1) to eviscerate as soon as the birds have been completely dressed in every detail, thoroughly washed, and then freeze the eviscerated birds at −20°F.; (2) to eviscerate after the dressed birds have been ice-chilled for 3 hr. and then freeze the eviscerated birds at −20°F.

During the process of evisceration, every precaution must be taken to prevent bacterial decomposition. In commercial dressing-plant evisceration, it is more sanitary to remove the viscera from the drawn birds while they are suspended from shackles rather than while the birds are resting on pans. Even so, a great deal of fecal contamination may be transferred from the worker's hands to the birds. Thorough washing after evisceration is most important.

In up-to-date dressing plants the evisceration process is carried out on a highly efficient basis, each of several stages of evisceration being performed by skilled specialists. As soon as the viscera are removed from each bird while it is still suspended from shackles, the bird and its viscera on a pan underneath are examined by an inspector. The hearts, livers, and gizzards are separated from the inedible viscera and are washed thoroughly. The inedible viscera are conveyed to separate containers. The eviscerated birds are washed thoroughly by spraying. The heads are removed and placed in separate metal containers. The insides of the birds are flushed with water. The feet and shanks are removed and placed in separate metal containers. The birds are then suspended from the shackles by the wings and are washed thoroughly by spraying under high pressure.

Cutting Up Chickens. The greatly increased commercial production of broilers and fryers during recent years has been accompanied by greatly increased sales of cut-up chicken ready for broiling or frying. Thousands of producers raise broilers and fryers in batteries on plants adjacent to cities and towns and deliver cut-up chicken to consumers or sell their cut-up chicken retail at stands or stalls in city markets. Battery-raised broilers and fryers in nearly all cases should be prepared for

consumption on the premises because there is usually excessive loss in weight in shipping or trucking these birds to market alive.

Enormous quantities of cut-up chicken are shipped from commercial poultry-dressing plants to retail distributing centers. This cut-up chicken is prepared from birds raised on the floor by commercial-broiler producers, the live birds being delivered in trucks to the dressing plants. In the dressing plants the birds are killed, dressed, and eviscerated as described previously. After the eviscerated birds have been thoroughly washed, the necks and wings are removed and are placed in pans which are conveyed to the packing section of the plant by a mechanically operated conveyor. An electrically operated band saw is used to cut a broiler in half for broiling or a fryer into 4 or 12 pieces. In the packing section of the dressing plant, the cut-up parts are placed in packages and are wrapped by hand or mechanically. Packages for consumers contain the respective parts of an eviscerated bird, including the heart, liver, and gizzard. Institutional packages may consist entirely of breasts, or thighs and drumsticks, or wings, or backs and necks, or livers, or gizzards, depending upon the demand from hotels and restaurants. In a few dressing plants, the feet and shanks are packed separately and sold for flavoring soup or for gelatin-manufacturing purposes.

Quick-freezing Poultry. The proper method of cooling dressed poultry in order to remove body heat as quickly as possible has already been discussed under the section on preparing poultry for consumption. The purpose of freezing poultry in poultry-dressing plants is to preserve the high quality of meat characteristic of fresh-killed birds. In some plants, dressed birds are packed in boxes immediately after being dressed and frozen at −20°F. or lower. There is some risk of a certain amount of spoilage occurring in the interior of the dressed bird before it becomes frozen. For this reason, most dressing plants stack the boxes in the freezing room with sufficient space between boxes to provide for thorough circulation of air around each box. Also, the freezing room is equipped with a freezing unit that circulates the air at high speed at a temperature from −25 to −50°F. The boxes of dressed poultry are often placed upside down in the freezing room in order to give the breasts a flattened appearance when the boxes are opened. Eviscerated and cut-up poultry is usually frozen at these low temperatures. The sale of quick-frozen poultry is steadily increasing.

It has been determined that between the temperatures of 21 and 25°F. approximately 75 per cent of the water contained in poultry flesh is frozen, this range in temperature being termed the zone of maximum crystal formation. The quick-freezing of poultry reduces the tempera-

ture through the crystallization zone very quickly so that the cells of the flesh are not ruptured. Quick-frozen poultry is of better quality, therefore, than poultry frozen at a slow-freezing rate as commonly employed several years ago.

Occasionally, when frozen poultry is withdrawn from the freezer unit, the leg bones and adjacent flesh are observed to have a dark-red appearance. This is caused by the leaching of the bloody marrow through the bones during freezing, thawing, and cooking. This condition is noticeable only in young chickens, apparently because of their incompletely calcified bones. Blanching cut-up chicken before freezing prevents bone darkening but adversely affects the flavor of the flesh. Storing poultry below −15°F. almost completely prevents the development of the condition.

Canning. The home canning of chickens has long been a popular method used by housewives to preserve quality in poultry meat. In this case, the chicken is preserved in jars for use during the winter and spring seasons of the year. The commercial canning of chicken meat is practiced extensively as well as the canning of eviscerated whole and halved chickens. Chicken meat is removed from the bones and is either canned separately and sterilized or is incorporated with noodles and other food products to provide a variety of canned-chicken products for consumer use.

Boning. Removing the bones from the flesh of an eviscerated bird and then forming the meat into a roll with the attached skin on the outside of the roll is a unique way of preparing chicken for serving roasted.

Smoking. Smoked chicken is not so extensively prepared for consumption as is smoked turkey, although the process is the same. The birds are "cured" in a brine solution and are then smoked, or the birds are treated with specially prepared mixtures having a smoke flavor.

Processing Chicken Fat. Fat removed from eviscerated birds is first liquefied at 180°F. in stainless-steel open kettles. The melted fat is drawn off and piped to a vacuum-rendering tank where it is homogenized under pressure. When the moisture has been extracted from the fat, it is siphoned off into cans. The cans are left open overnight during which time fans are used to lower the temperature of the fat to about 90°F. The next morning the finished product is placed in glass jars and the processed fat is further cooled for shipment to the retail trade.

PROPORTIONS OF EDIBLE MEAT AND OFFAL

The edible meat of a bird consists of the flesh, fat, and edible viscera. The heart, liver, and gizzard are often called "giblets." The offal has usually been thought of as the head, feet and shanks, and the inedible

viscera, but since the blood, feathers, and bones are not consumed, they might well be considered as offal.

Numerous factors affect the proportions of edible meat to offal in market poultry. During the latter part of the growing period, the weight of flesh increases at a relatively faster rate than the increase in the weight of the bones. Females accumulate more fat than males, especially after sexual maturity has been attained. The proportion of offal to body weight in unfattened birds is relatively greater than in fattened birds.

One of the most disturbing factors in determining the proportions of edible meat and offal in slaughtered poultry is the amount of feed that may be present in the crop and the rest of the intestinal tract at the time of slaughtering. Birds fasted for 24 hr. before being killed usually have about 50 per cent as much feed in the crop and intestinal tract as birds that are fed all that they will eat up to the time of being killed. The amount of feed in the intestinal tract of birds fasted 3 or 4 hr. before being killed usually amounts to about 2.5 per cent of the live-body weight. The undigested feed material is included with the intestinal tract as offal.

The effect of fattening poultry on the percentage of edible meat in relation to dressed and live weights, respectively, is shown in Table 52.

TABLE 52. PERCENTAGE DRESSED WEIGHT OF LIVE WEIGHT AND EDIBLE MEAT OF DRESSED AND LIVE WEIGHTS, RESPECTIVELY, IN BROILERS, ROASTERS, CAPONS, AND HENS
(M. A. Jull and W. A. Maw, 1923)

Class	Average live weight, lb.	Dressed weight of live weight, per cent	Edible meat of dressed weight, per cent	Edible meat of live weight, per cent
Unfattened broilers	2.65	88.3	54.3	47.9
Fattened broilers	2.72	90.8	60.7	55.2
Unfattened roasters	4.42	88.9	56.9	50.6
Fattened roasters	6.25	91.7	63.1	57.8
Fattened capons	7.72	92.0	67.5	62.1
Fattened hens	5.77	92.0	64.2	59.1

The data in Table 52 show that fattening increased the percentage of edible meat in broilers and roasters over 6 per cent. Many of the broilers, fryers, and roasters produced commercially at present are not fattened to the same extent as was the custom several years ago. Not only does the degree of fattening affect the edible-meat percentage of dressed and live weight, respectively, but so also does the extent to

which a particular strain of birds has been bred for superior breast fleshing.

The amount of blood lost in killing varies from about 3.5 to 4.5 per cent of the live-body weight, small birds losing relatively more blood in proportion to body weight than large birds. The weight of the feathers varies from about 4.5 to 7.5 per cent of the live-body weight, being relatively greater in large than in small birds. The dressed weight amounts to about 88 to 90 per cent of the live weight, depending upon the size of the birds. The ready-to-cook weight, including the edible viscera, varies from about 75 to 83 per cent of the dressed weight and from about 66 to 76 per cent of the live weight. These wide variations are due primarily to differences in the size of birds, differences in degree of fattening, and the extent to which the degree of inherent breast fleshing varies among the different groups of birds slaughtered. It is obvious, therefore, that no

TABLE 53. APPROXIMATE PERCENTAGE OF LIVE WEIGHT OF CHICKENS CONTRIBUTED BY THE BREAST, HUMERI, AND LEGS
(M. A. Jull, R. E. Phillips, and C. S. Williams, 1943)

Portion	3.3-lb. males	3.0-lb. males	3.0-lb. females
Breast	17.0	16.6	17.4
Humeri	4.3	4.2	4.1
Legs	23.5	23.5	22.3
Total	44.8	44.3	43.8

standard set of figures can be given concerning the percentages of inedible or edible portions of the dressed and live weights, respectively, for any particular class of birds. The bones in ready-to-cook birds amount to about 17 to 22 per cent of the ready-to-cook weight.

Since the sale of cut-up chicken has been an important factor in the increased consumption of chicken meat that has taken place in this country during recent years, it is of interest to know the approximate proportion of meat contributed by the breast and legs of broilers and fryers in relation to live-body weight. The data in Table 53 pertain to New Hampshires grown in batteries and include the weight of the humerus section of the wings because they are often sold with the breast. The breast, humerus sections of the wing, and the legs are the highest-priced portions of cut-up chicken sold, except for the liver.

The data in Table 53 show that the three most important parts of cut-up chickens constitute about 44 per cent of their live weight. The breast consisted of about 84 per cent meat and about 16 per cent bone,

the humeri about 71 per cent meat and about 29 per cent bone, the legs about 79 per cent meat and about 21 per cent bone. The weight of the legs, including meat and bone, was greater than the weight of the breast, including meat and bone, and although there was relatively more meat in proportion to bone on the breast than on the legs, the legs of these birds actually contributed more meat than did the breasts.

The birds for these determinations were not fattened. Birds reared on the floor, as is the case with most commercially raised broilers and fryers, and especially if they had been given a fattening ration for about 2 weeks before killing time, would undoubtedly yield a higher percentage of breast meat than the figure presented above. In the case of these battery-raised birds, the meat of the breast, humerus section of the wings, and the legs contributed about 70 per cent of the total edible meat.

Utilizing By-products. The by-products in the commercial dressing and evisceration of poultry include the blood, feathers, heads, feet and shanks, inedible viscera, dead birds, and manure. In many dressing and eviscerating plants, these by-products accumulate in sufficient quantities to justify preparing them for efficient utilization. In many cases, dressing-plant operators either give these by-products away or pay to have them hauled from the premises. If the by-product could be processed and sold at a profit, the over-all operating costs of the dressing plant would be reduced and the by-products would serve a more useful purpose.

At killing time, the blood, for the most part, is allowed to run down the drain. Research has indicated, however, that the protein constituents of blood are of some value in supplementing rations for feeding purposes.

Feathers have long been used for pillows, mattresses, and similar purposes, in which case feathers obtained from dry-plucked birds are most desirable. In practically all dressing plants, however, the feathers are wet-plucked but can be treated with a preservative in the proportion of 15 lb. table salt, 1 pt. of commercial concentrated hydrochloric acid dissolved in 30 gal. of water, this amount of preservative being added to 15 lb. of wet feathers. The feathers should be stirred occasionally. The preservation prevents decomposition, and the fluffiness of the feathers is not injured. They can then be dried in specially prepared driers through which warm air is forced.

Feathers make excellent insulating material and have been used as such in lining aviators' jackets. Fibers have been spun from feathers for producing a fabric used in making clothes. Plastics and adhesives are also made from specially processed feathers. The protein constituents of feathers can be prepared as a protein supplement in feeding rations.

Heads, feet and shanks, and inedible viscera are usually used either as

hog feed or hauled out to the land for fertilizing purposes. In some dressing plants these materials are used in the manufacture of dog and fox feed. The results of research have indicated that more efficient use can be made of these by-products if they are made into chicken scrap, soap, and lubricating oil. Hens and fattened roasters have relatively more fat and less water in proportion to body weight than broilers and fryers. In the process of rendering the by-products for making chicken scrap, a portion of the fat is made into soap and the rest into a lubricant. Before the by-products are ground for rendering, the grit must be removed from the lining of the gizzards, or the linings with adhering grit discarded, in order to avoid damage to the grinding machinery. When the products are dry rendered, the finely ground material is put into a hydraulic press and is pressed into cakes. The chicken scrap contains approximately 55 per cent protein and has been found to be a satisfactory protein supplement in poultry rations.

The manure that accumulates in the feeding sections of dressing plants can be utilized in a manner similar to that mentioned in the chapter on Housing and Yarding Principlės and Practice.

PACKING DRESSED AND OTHER POULTRY

Dressed poultry is packed dry or in ice in boxes or barrels. Quick-frozen, ready-to-cook, and cut-up poultry is packed in boxes or cartons.

Wrapping Heads. Dressed poultry that is to be packed dry for shipment presents a much more attractive appearance if the heads are

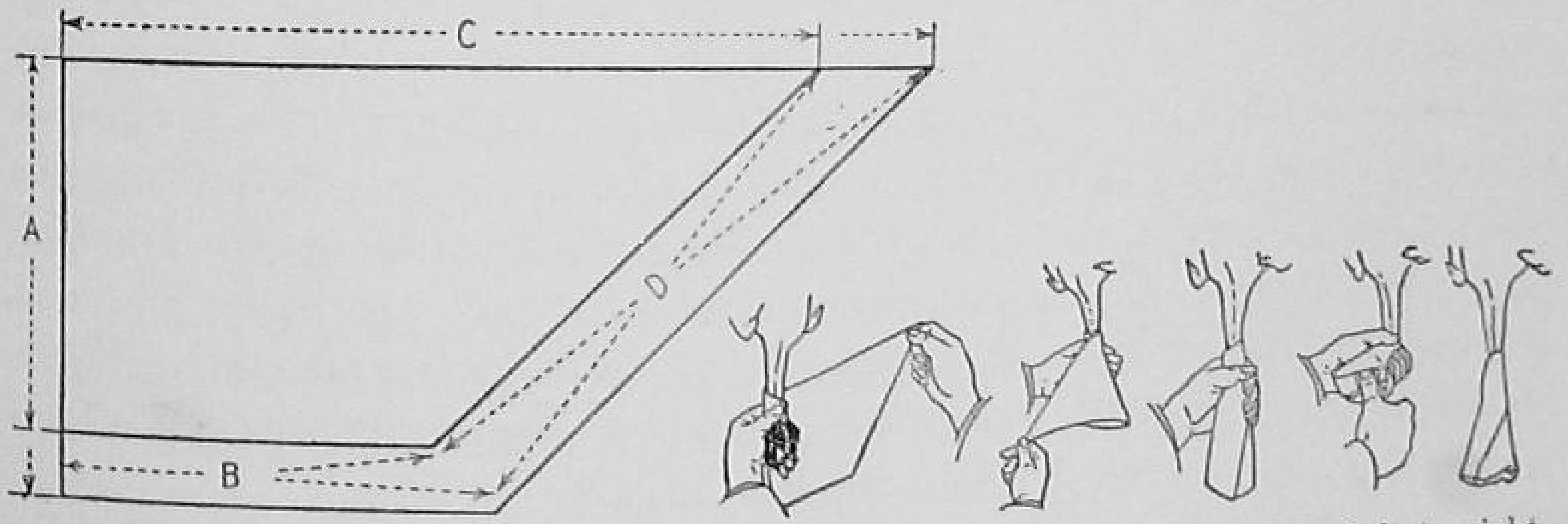

Fig. 232. Showing method of wrapping heads, in progressive steps from left to right. The lengths in inches of the different sides of head wraps are as follows:

	A	*B*	*C*	*D*
For broilers	6	6	12	7
For roasters and fowl	7	7	14	10

wrapped before being packed. For this purpose, parchment, draft paper, or better still, draft paper waxed on one side is used. One end of the paper is cut on the diagonal, which makes it possible to wrap the head very neatly.

Ice Packing. Ice packing of dressed poultry is, for the most part, limited to dressing plants located within such distance of retail markets so that the poultry can be delivered the same day or the morning after it is packed. In some commercial-broiler-producing areas, the dressed birds are packed in cracked ice in boxlike containers, lined with parchment paper, and shipped in refrigerated cars or trucks to nearby markets. This is possible where the commercial dressing plants in the broiler-producing areas are an overnight shipping distance from the consuming center, as in the case of Delmarva (composed of the adjacent counties of Delaware, Maryland, and Virginia) broiler industry in relation to the New York City, Philadelphia, Baltimore, and Washington markets. The ice-packed poultry should be sold to consumers within 3 days after its arrival. The advantage of this form in which dressed poultry is marketed is that consumers are satisfied that they are purchasing fresh-killed poultry. Barrels are also used for shipping ice-packed dressed poultry to market. Each barrel should be lined with parchment paper. Approximately 6 in. of crushed ice is placed in the bottom of the barrel, then a layer of birds, and in succession alternately 3 in. of ice and a layer of birds to within about 6 in. of the top of the barrel, which is filled with crushed ice, and a burlap or board covering securely fastened in place.

Dry Packing. Barrels for dry-packed poultry include the sugar type and octagon-shaped veneer type, the tops in each case usually being of wood. Boring holes in the sides and bottom provide for proper ventilation. Each barrel is lined with parchment paper, enough being used around the sides so that when the barrel is filled, enough parchment paper can be folded over to cover the top layer of birds. Each layer of birds is covered with a sheet of parchment paper, a hole being made in the center of each sheet except the top and bottom ones. Broilers, fryers, and roasters should be individually wrapped, except for the legs, in parchment paper, especially if the birds are to be frozen solid. When the birds are individually wrapped, it is not necessary to place sheets of parchment paper between the layers of birds.

Boxes for dry-packed, dressed, and eviscerated poultry are made of gum, spruce, tupelo, and cottonwood. Wire-bound veneer and fiber boxes are also used, the former being relatively light in weight but not always rigid enough to prevent damage to the birds, and the latter sometimes not being satisfactory for holding birds in cold-storage warehouses because of the moisture-absorption capacity of the fiber. Most boxes are made of such shape and design to hold 1 doz. birds, although boxes holding ½ doz. birds are used to some extent. Each box is lined with parchment, wax-coated or plastic-film paper, cellophane, or other mate-

rial, such as a waterproof, moistureproof, asphalt-centered paper lining. In some cases each bird is individually wrapped.

Cartons made of cardboard are used for packing eviscerated individual or cut-up birds for shipment to retail markets or private customers. The tops of some of these cartons have cellophane windows which enable customers to see the contents. Breasts, legs, livers, and gizzards are sometimes packed separately in 1-lb. cartons laminated on the inside

FIG. 233. Ready-to-cook poultry keeps better when enclosed in a tight-fitting plastic bag. Left, the ready-to-cook bird is placed head downward in the plastic bag. Right, the top of the bag is drawn together and a short metal tube inserted in the opening. The bird is then immersed momentarily in heated water, which shrinks the bag instantaneously. (*Dewey and Almy Chemical Company.*)

with moistureproof cellophane. An outer wrapping of moistureproof cellophane around the products before they are placed in the carton provides double protection and adds to their appearance.

An interesting method of packaging eviscerated birds (ready for the oven) is by placing them in a thermoplastic film bag which is drawn tightly around the bird, as described later, so that there is practically no air between the film and the bird. This tends to prevent dehydration of the skin. This method of packaging eviscerated birds is quite satisfactory for preparing poultry at home for storing in the frozen-food

locker. The method is also being used in some poultry-dressing and packing plants. The procedure followed in the home is illustrated in Figs. 233 and 234. Each bird is placed in the thermoplastic film bag, head downward, and the top of the bag is drawn tightly around a short piece of tubing that is inserted into the bag until it touches the bird. Holding the free end of the bag tightly around the tubing, the bird is immersed momentarily in water heated to a temperature of about 185 to 195°F. The bag shrinks instantly, driving out most of the air. Upon

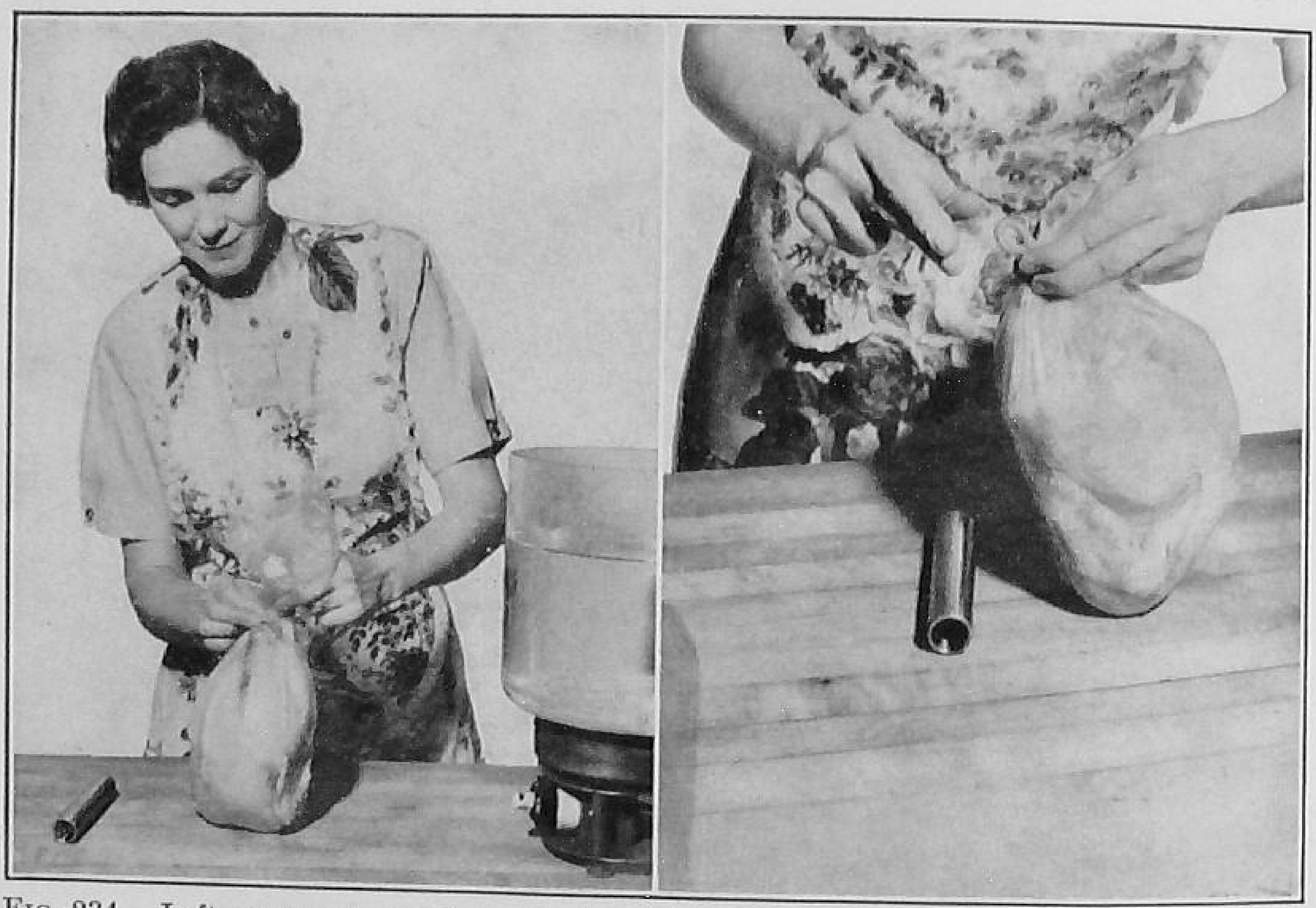

FIG. 234. Left, upon removal from the heated water, the tube is withdrawn from the top of the bag and the small amount of air remaining in the bag is forced out by hand. Right, the end of the bag is twisted and doubled over, then held in place by a strong rubber band or other fastener. (*Dewey and Almy Chemical Company.*)

removal from the heated water, the tube is withdrawn, and what little air remains in the top of the bag is squeezed out by hand. The loose end of the bag is twisted firmly, doubled over, and held securely by a strong rubber band. The bird with its tightly fitting thermoplastic film is now ready to be quick frozen. In commercial dressing plants, the air is withdrawn from the bag containing the bird by operating the foot pedal of a sealing machine attached to a vacuum line.

Styles of Dry Packing. The three principal styles of dry packing dressed poultry include the breast pack, the double-layer side pack, and the single-layer side pack. Of these three styles, the breast pack is the one most generally used. In the breast pack, the birds are placed one row of 6 birds on each side of the box with their breasts up and toward

the outside of the box, the legs of each bird in one row being placed under the back of each bird in the opposite row. The double-layer side pack consists of two layers of 6 birds, each layer having two rows of 3 birds with breasts toward the outside of the box. Although this is the most compact method of packing dressed poultry, it has the disadvantage of preventing the prospective buyer from seeing the lower layer of 6 birds when the box is opened. The single-layer side pack consists of 6 birds laid on their sides in two rows with breasts toward the sides of the box.

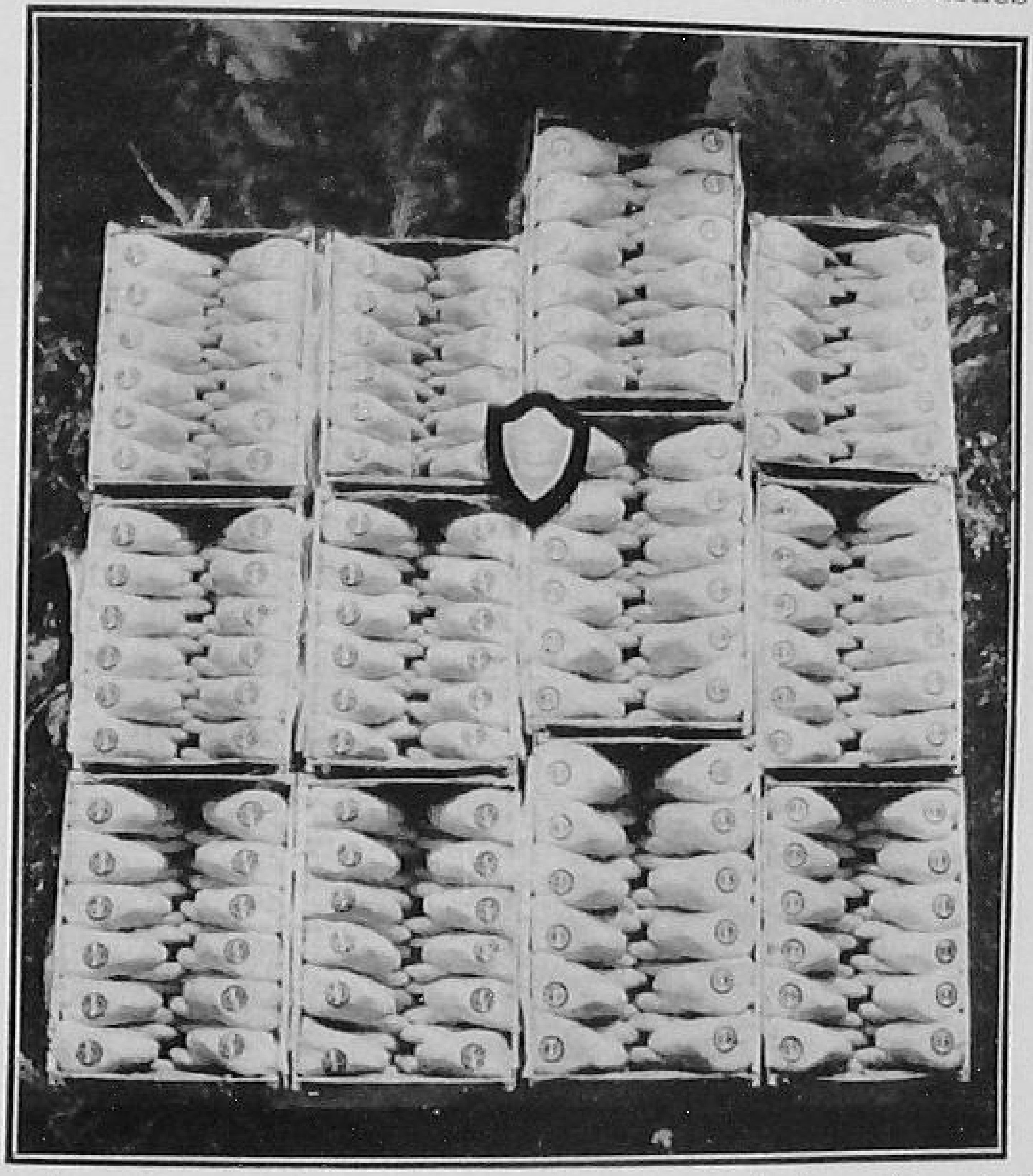

FIG. 235. An attractive exhibit of high-quality box-packed poultry of different sizes. (*American Egg and Poultry Review.*)

With respect to both the double-layer and single-layer side pack, the extent of breast fleshing is not discernible when the box is opened.

A method of packing dressed poultry designed to save space and reduce shipping costs consists of removing the head of each bird by severing the neck between the base of the skull and the first vertebra and removing the feet and shanks by severing the latter ¼ in. below the hock joint.

In order to make the dressed birds look as attractive as possible when the box is opened for the inspection of prospective purchasers, some dressing-plant operators cover the legs of the birds with white or colored shredded waxed paper. Some operators also place brand labels on the breast of the birds at packing time.

All containers in which dressed and other forms of poultry are packed should be plainly stamped on the outside, either by code numbers or by other means, indicating the kind of poultry contained therein. The range in weights per bird and per dozen should be indicated. The number of the packer who packed the poultry should be indicated, either by a stamped letter on the outside of the box or on a slip of paper on the inside of the box.

When the packing job is completed, the boxes are stacked in a cool room according to grades and sizes or are transferred to a freezing room for sharp chilling.

Holding in Cold Storage. Except for broilers raised commercially in large numbers the year round, the most extensive marketing of poultry

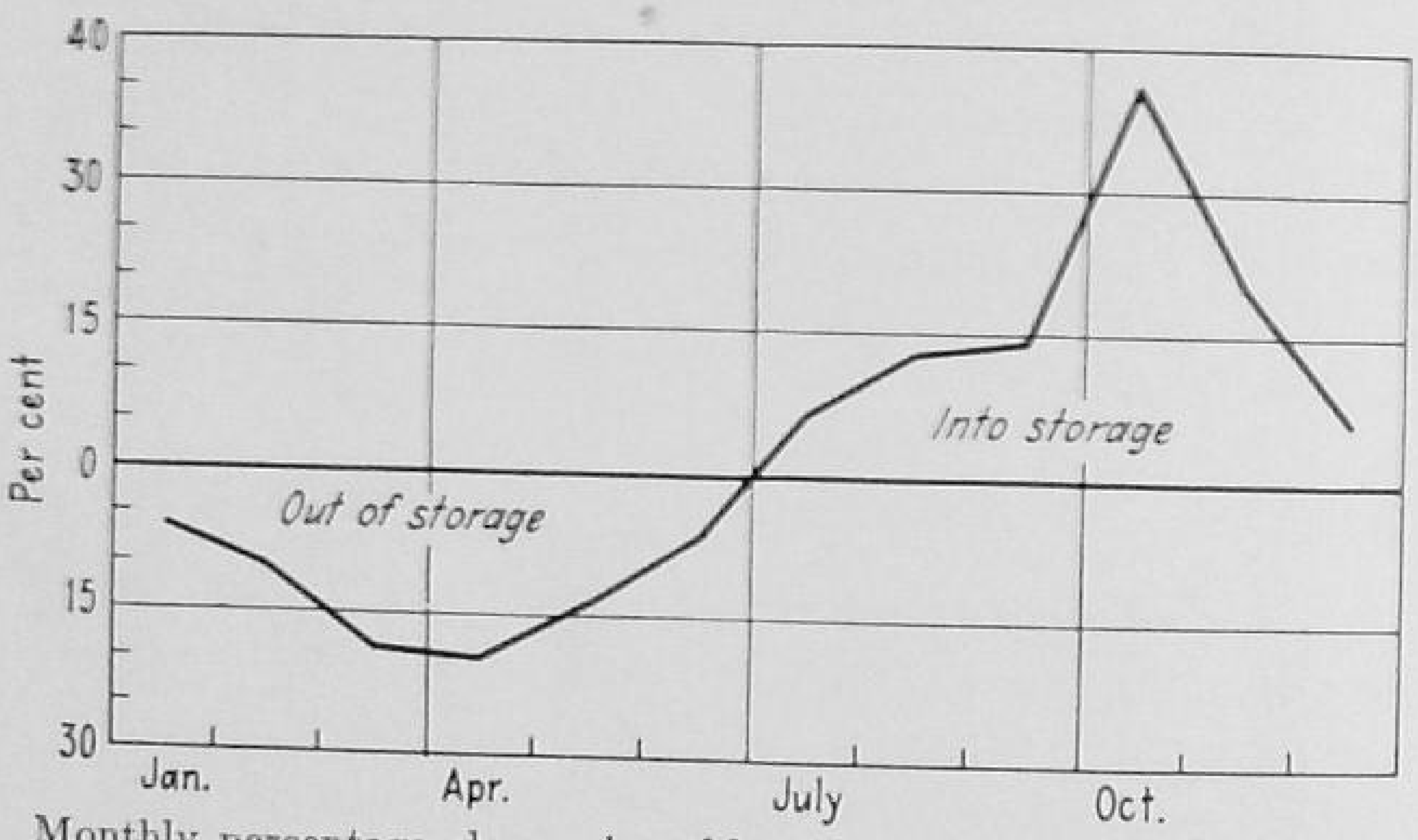

FIG. 236. Monthly percentage change in cold-storage stocks of frozen poultry, 1943 to 1947 average. (*Production and Marketing Administration, U.S. Dept. Agr.*)

takes place in the late summer and early fall. These marketings consist largely of farm-raised cockerels and hens culled from the laying flocks. Far more poultry is marketed from August to November than can be consumed during those months so that large quantities of dressed and other kinds of poultry must be placed in cold storage to be sold during the late winter and spring months when the quantities of fresh-killed poultry are not sufficient to meet the consumer demand for poultry meat. The movement of poultry into and out of storage is shown in Fig. 236.

Consumers usually prefer fresh-killed poultry to cold-storage poultry because the former is usually superior to the latter with respect to aroma, flavor, juiciness, and tenderness. Two of the most important problems in storing poultry for several weeks or months are to prevent excessive desiccation and the development of off-flavor.

Normal chicken tissue contains about 72 per cent moisture and, unless the atmosphere in the cold-storage room in which poultry is held has a

relative humidity of at least 95 per cent, the tissue loses an excessive amount of moisture. Desiccation is usually evident first in the skin around the feather follicles, but if the storage room is relatively low in relative humidity and the birds are held for several months, other areas of the skin show evidence of drying out. This condition is known as "freezer burn." The circulation of air in the cold-storage room increases the rate of desiccation. Wrapping birds individually in waxed, moisture-proof paper, or similar materials, and sealing the paper lining on the inside of a box of poultry very greatly reduce desiccation.

Poultry fat showing freezer burn has a tendency to become rancid. Desiccation of the skin of birds accelerates peroxide-oxygen formation, which decreases as the temperature of the cold-storage room is lowered and as the relative humidity increases at constant temperature. The most important factor in the development of rancidity in poultry held in cold storage is temperature. The temperature of poultry cold-storage rooms should be held at −10 to −20°F. or even lower, and the relative humidity should be in excess of 95 per cent. The temperature employed should be kept constant. Power atomizers are sometimes used to maintain high humidity.

MARKETING PROBLEMS IN RELATION TO PRODUCTION

Although chickens are raised in all parts of the United States, in some states the per capita production of chicken meat is far in excess of per capita consumption. From these states enormous shipments must be made annually to the industrialized consuming centers. In other states, especially in the highly industrialized section of the Northeast, per capita consumption exceeds per capita production so that poultry must be brought in from other states. Also, in the industrialized states there is much greater opportunity for producers to prepare a portion of their poultry for direct sale to consumers than in the Middle West.

Geographical Distribution of Production. During the 3-year period, 1945 to 1947, the first 10 states in yearly average number of pounds of farm-raised chickens and commercial broilers sold ranked as follows:

State	Thousands of pounds	State	Thousands of pounds
Iowa	213,670	Illinois	130,577
Texas	196,453	Missouri	126,106
Delaware	186,065	Indiana	114,137
Minnesota	156,113	Maryland	109,607
Pennsylvania	142,542	Ohio	108,127

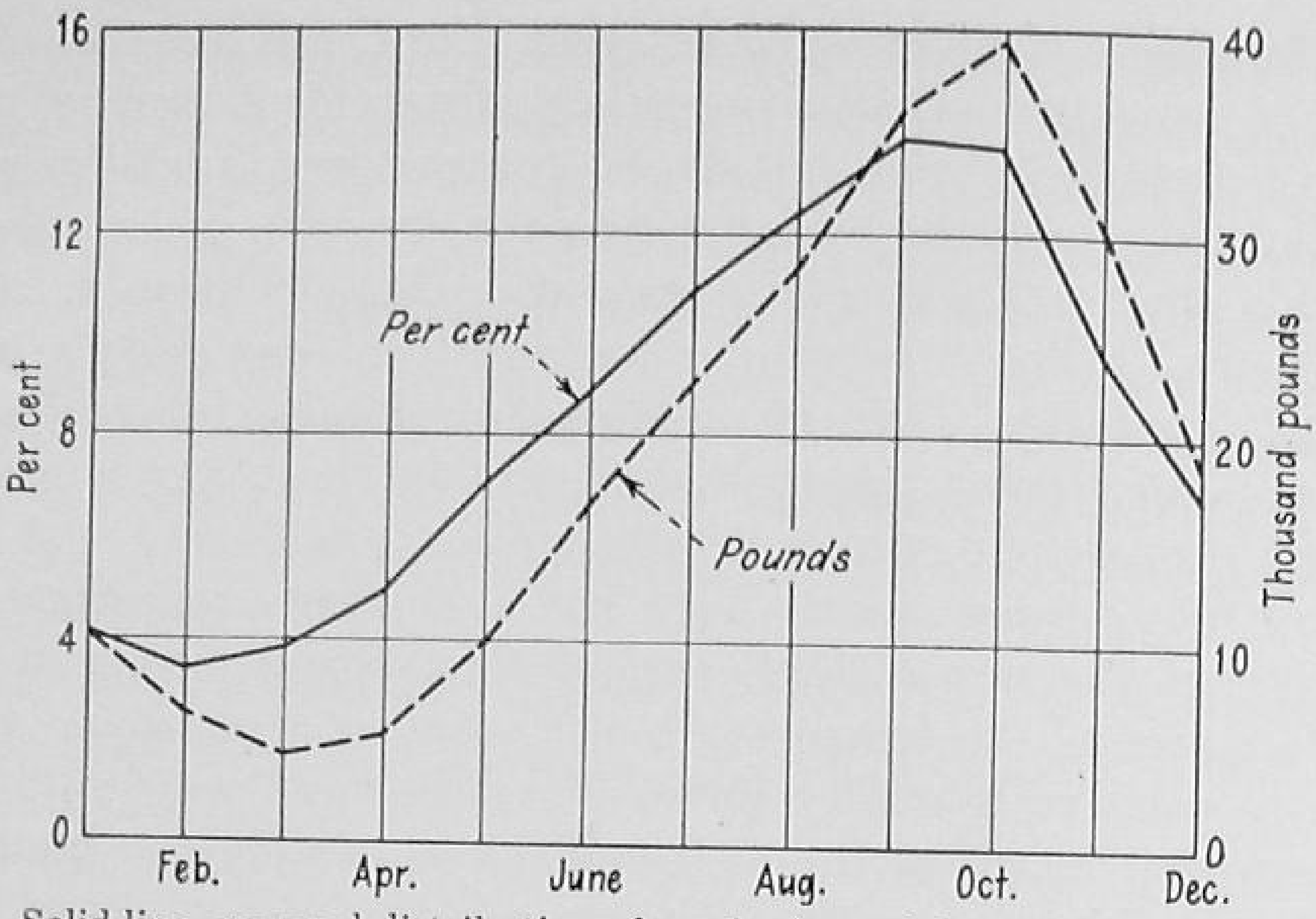

FIG. 237. Solid line, seasonal distribution of marketings of farm chickens, excluding commercial broilers, as a percentage of total marketings of farm chickens in the United States, 1943 to 1948. Slightly over 50 per cent of all farm chickens, not including broilers, were marketed during July, August, September, and October. Dotted line, monthly average weekly receipts of chickens, in thousands of pounds per plant, in Middle Western primary markets, 1943 to 1948. (*Graph made from data of Bur. Agr. Econ., U.S. Dept. Agr.*)

Seven of these 10 states are in the Middle West. Texas and New York were eleventh and twelfth with respect to yearly average pounds sold, and next to them came Kansas, California, Wisconsin, and Michigan. In addition to Delaware and Maryland, other states that sold

TABLE 54. DATES OF HEBREW HOLIDAYS, 1951 TO 1955

Name of holiday	1951	1952	1953	1954	1955
Purim	Feb. 20	Mar. 11	Mar. 1	Feb. 17	Mar. 18
Pesach (Passover)	Apr. 21 to Apr. 28	Apr. 10 to Apr. 17	Mar. 31 to Apr. 7	Apr. 18 to Apr. 25	Apr. 7 to Apr. 14
Rosh Hashana (New Year)	Oct. 1, 2	Sept. 20, 21	Sept. 10, 11	Sept. 28, 29	Sept. 17, 18
Yom Kippur (Day of Atonement)	Oct. 10	Sept. 29	Sept. 19	Oct. 7	Sept. 26
Succoth (Feast of Tabernacles)	Oct. 15 to Oct. 21	Oct. 4 to Oct. 10	Sept. 24 to Sept. 30	Oct. 12 to Oct. 17	Oct. 1 to Oct. 7
Hanukkah	Dec. 24 to Dec. 31	Dec. 13 to Dec. 20	Dec. 2 to Dec. 9	Dec. 20 to Dec. 27	Dec. 10 to Dec. 17

relatively large volumes of broilers were: Virginia, Georgia, Arkansas, and North Carolina.

Seasonal Levels of Marketing. Broilers are marketed in relatively large numbers every month of the year, but the marketing of farm-raised chickens and birds culled from the laying flocks follows a definite

trend, as shown in Fig. 237. Farm-raised fryers and roasters as well as culled hens are marketed in relatively greatest numbers from July to November. Dressing plants located in commercial-broiler-producing areas operate at relatively the same capacity throughout the year, whereas dressing plants in the Middle West have a slack season from January to about June.

Hebrew Holidays. Since the Jewish trade demands so much live poultry, live-poultry shippers are interested in Hebrew holidays, because for certain holidays the demand for a particular kind of live poultry is much greater than at other times. The two most important holidays are Pessach (Passover) and Yom Kippur (Day of Atonement).

POULTRY-MARKETING METHODS

It has already been pointed out that some live, dressed, ready-to-cook, and cut-up poultry is sold directly to consumers. The great bulk of these different kinds of poultry, however, passes through much the same marketing channels through which eggs pass.

Cooperative Marketing. Many of the cooperative organizations that operate country-point egg auctions sell live poultry. The birds are delivered by members to the auction to be sold on a certain day of the week. In some sections of the country other cooperatives buy live poultry from their members and kill and dress the birds for shipment to consuming centers.

Other Marketing Channels. Relatively few chickens are bought by hucksters, who in turn sell them to live-poultry shippers. Commercial truckers operate principally in commercial-broiler-producing areas, live broilers being delivered principally to the larger live-poultry city markets, where the birds are either sold alive to the Jewish trade and then slaughtered or are delivered to city dressing plants. Live-poultry shippers and wholesalers of live chickens buy live chickens in the country and ship them in trucks or live-poultry cars to terminal city markets. Most of the chickens produced annually are bought by operators of dressing and packing plants where the birds are prepared for consumer use, as described previously. Dressed, ready-to-cook, and cut-up poultry is marketed through various channels, as shown in Fig. 238. From the time it is sold alive on the producers' premises until it is sold to city consumers, much of the poultry produced annually passes through a devious channel.

Retailing Poultry. Except for the considerable numbers of live chickens that are bought by Jewish housewives at city slaughter-houses, very few producers sell live chickens directly to consumers. The retail trade in poultry consists almost entirely of dressed, ready-to-cook, or cut-up chickens. For the most part, this poultry is sold by chain stores, inde-

pendent stores, butcher shops, and specialized units or stands that sell cut-up chicken exclusively. Roadside stands operated by producers living near cities provide a means of retailing poultry in various forms to consumers.

In all cases of retailing dressed, ready-to-cook, and cut-up poultry, the chickens should be kept completely, or nearly completely, covered with crushed ice in the display case to prevent spoilage.

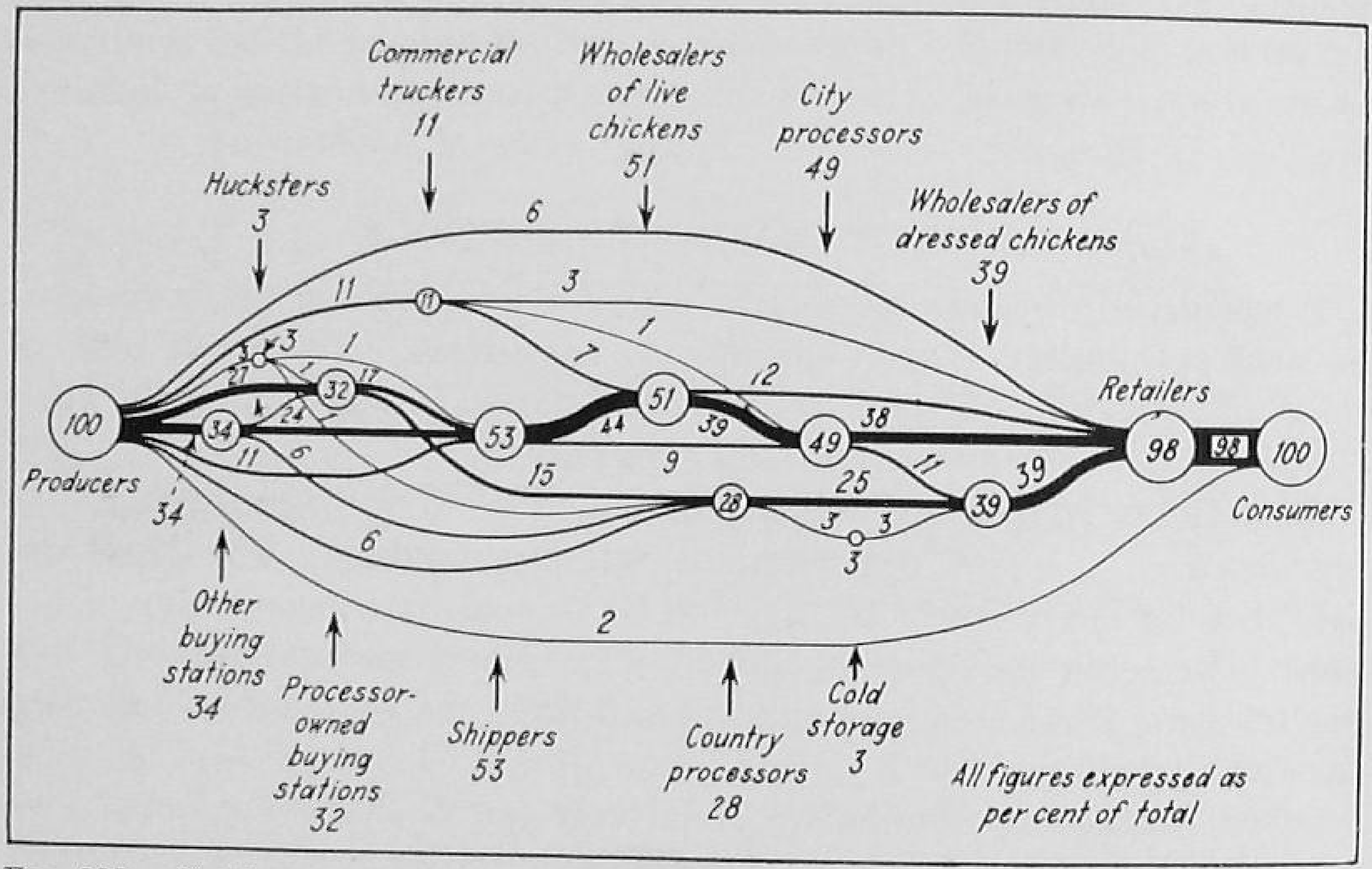

FIG. 238. Chickens are marketed through a variety of channels from producers to consumers. Processing is carried on in country and city plants, mostly the former. The typical channel through which most poultry passes consists of five agencies, buying-station operator, shipper, wholesaler, processor, and retailer. (*E. P. Winter*, 1948.)

Defrosting Frozen Poultry. Frozen dressed poultry delivered to retail stores should be defrosted gradually by placing the box-packed birds in a refrigerator or in a room in which the temperature is about 45°F. and holding them there overnight. Removing the lid of the box hastens defrosting, and laying a cloth over the birds tends to prevent moisture from condensing on the birds. If hastening defrosting is absolutely necessary, the birds may be immersed in cold water and then dried by patting gently with a clean cloth.

POULTRY-TRANSPORTATION PROBLEMS

Poultry is transported in railroad cars, trucks, boats in certain cases, by express service, and by parcel post to a limited extent.

Live-poultry Cars and Trucks. During recent years much more live poultry has been shipped in trucks than in railroad cars. Poultry that

is shipped long distances requires special handling and feeding and watering during transit to prevent excessive loss in weight. The capacity of a live-poultry car is approximately 4,000 or 5,000 birds, depending upon their size, weighing about 18,000 lb. for fowl and roasters and about 14,000 lb. for broilers. The carrying capacity of trucks varies considerably, some holding almost as much as a car. The birds are weighed when loaded and again when unloaded. Competent attendants are sometimes able to secure gains in weight during shipment. The last feeding before arrival at the terminal market should be adjusted so that not more than 2 oz. of feed remains in the crop by the time the poultry is unloaded.

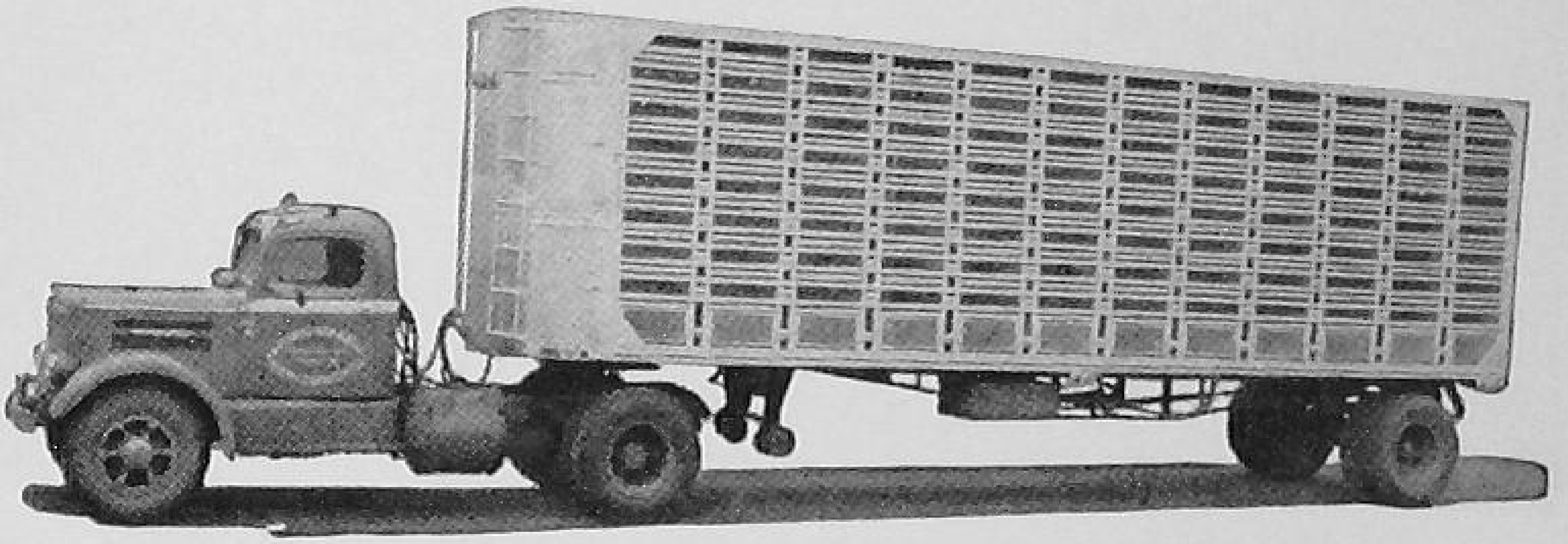

FIG. 239. A live-poultry truck. (*The Poultryman.*)

Conditions under which live poultry is bought and sold at such terminal markets as may be designated by the Secretary of Agriculture of the United States government require that live-poultry dealers must obtain Federal licenses and that trading must be supervised as for other classes of livestock.

Cars and Trucks for Ice-packed Poultry. It has already been pointed out that in several commercial-broiler-producing areas fresh-killed, ice-packed broilers and fryers are shipped to city receiving markets in cars or trucks, usually the latter. These cars and trucks are well insulated and are provided with ventilating devices to ensure the arrival of poultry in good condition during short-distance hauls.

Refrigerated Cars and Trucks. Dressed and ready-to-cook poultry and cut-up chicken prepared in dressing plants are shipped largely in refrigerated cars and trucks to the receiving centers or to cold-storage warehouses to be held in storage for later delivery to receiving centers. The cars and trucks are thoroughly insulated and proper refrigeration is maintained during transit by using cracked ice in bunkers through which air is circulated or by mechanical refrigeration. The internal temperature of the car or truck should be maintained at from 15 to 20°F. for frozen poultry.

FIG. 240. A live-poultry car. (*J. M. Gwin, University of Maryland.*)

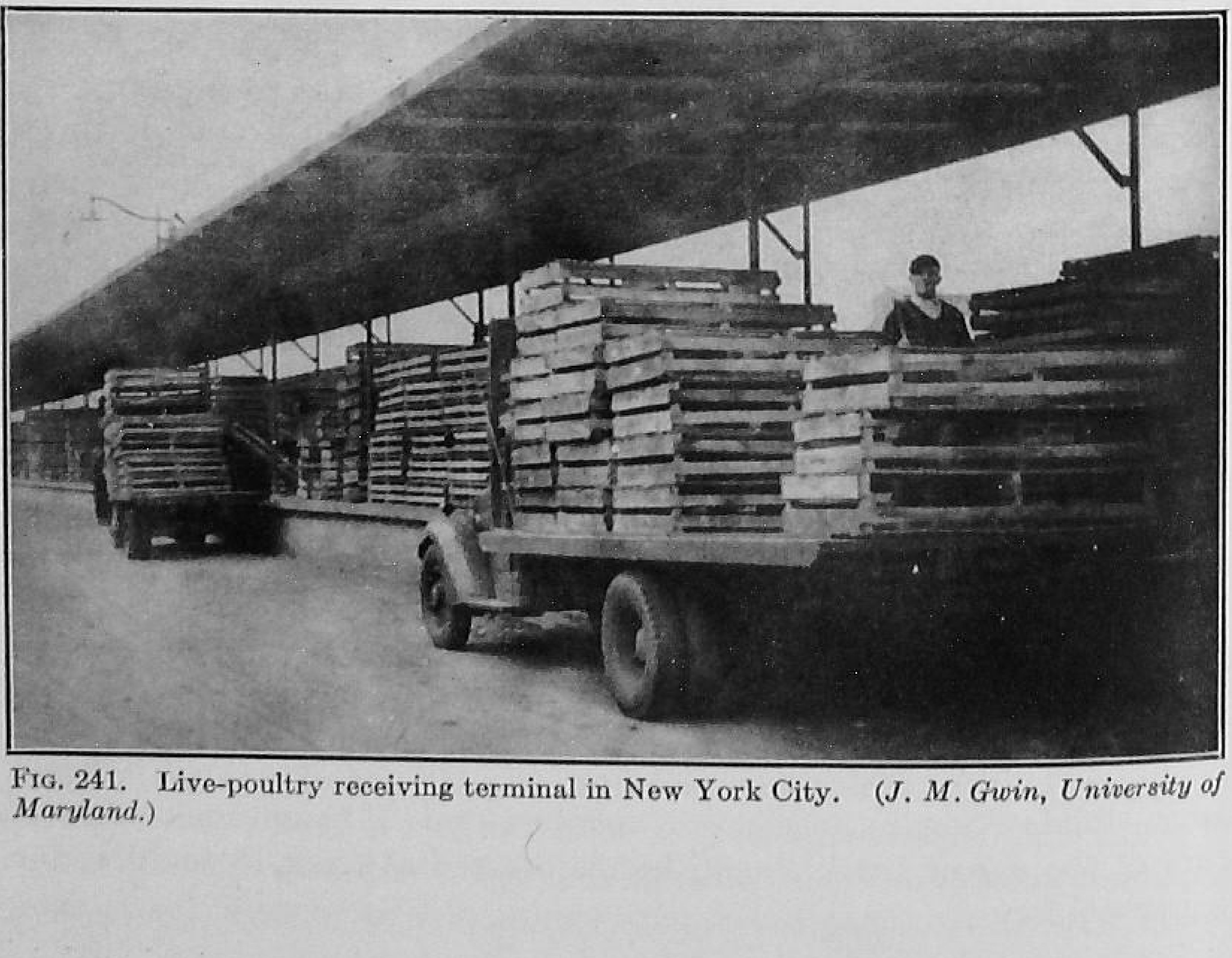

FIG. 241. Live-poultry receiving terminal in New York City. (*J. M. Gwin, University of Maryland.*)

POULTRY MARKETING COSTS

Among the various items of cost in marketing poultry, the cost of retailing is relatively the greatest, as indicated by the data in Fig. 242. For 1939 it is shown that an average of 44.6 cents of the consumer's

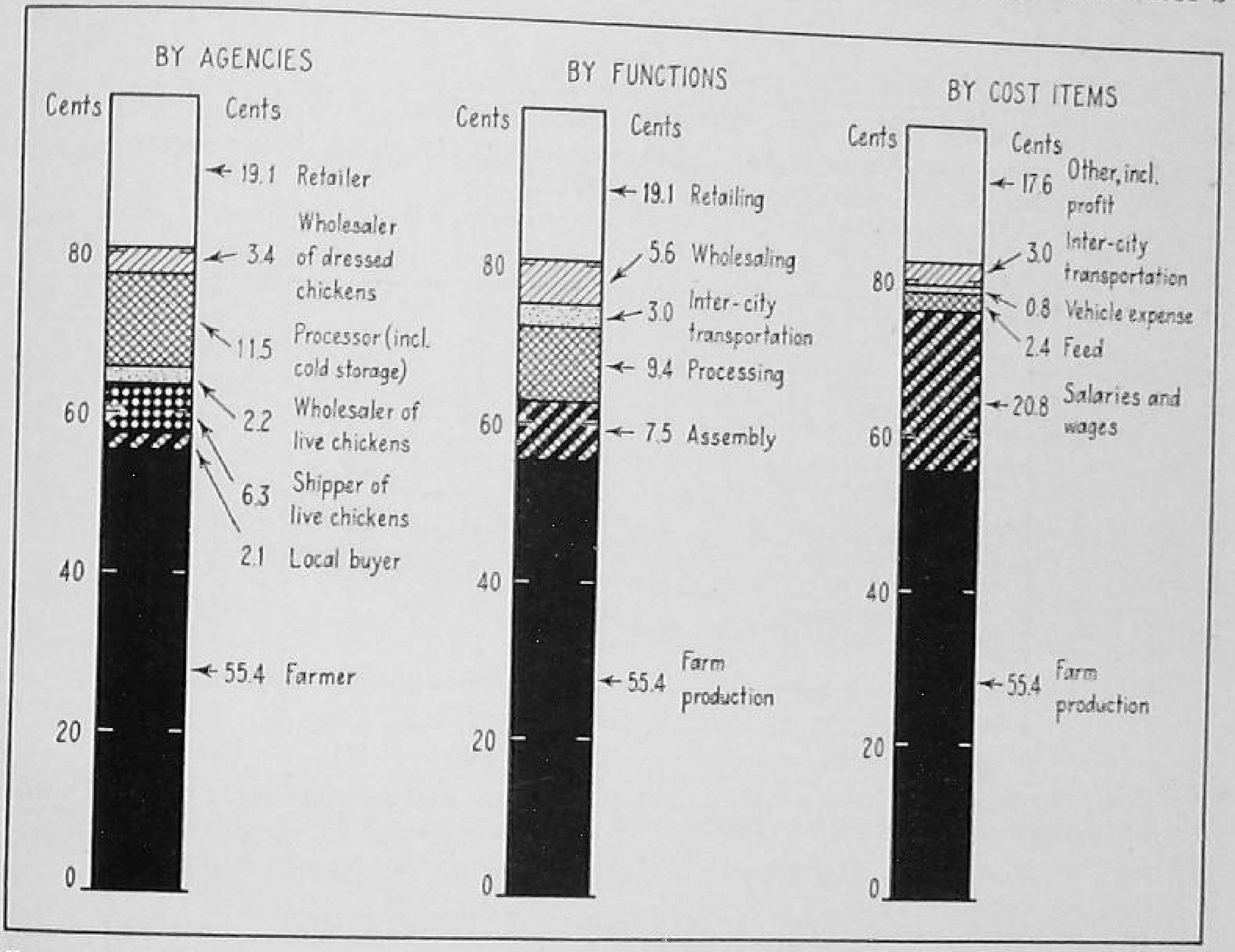

FIG. 242. Chickens: approximate distribution of the consumer's dollar, by marketing agencies, by marketing functions, and by cost items, United States, 1939. (*Based on official and other data and partly estimated. E. P. Winter*, 1948.)

dollar spent for poultry was accounted for by marketing and an average of 55.4 cents went to producers. From 1913 to 1948, for each of six 6-year periods, the average poultry producer's share of the consumer's dollar spent for poultry was as follows:

1913 to 1918	1919 to 1924	1925 to 1930	1931 to 1936	1937 to 1942	1943 to 1948
63	60	61	50	57	63

FACTORS AFFECTING POULTRY PRICES

Available and potential supplies of poultry, in relation to demand for same, affect prices to a major extent. Another factor affecting the price of poultry is the relative price of red meats of various kinds. The price of poultry may fluctuate slightly from day to day or week to week by the apparent supply and the apparent demand, the sentiment of poultry buyers and sellers being involved. The quality of broilers, fryers, and

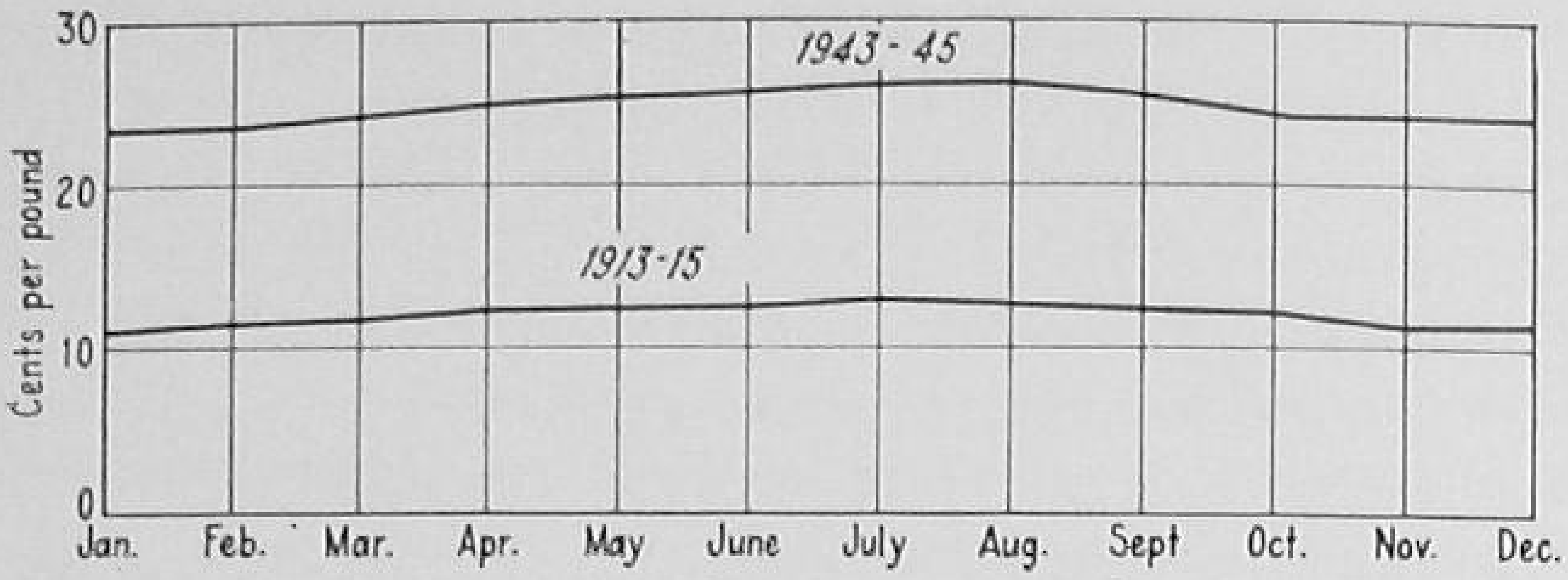

FIG. 243. Average monthly prices of chickens per pound. Top line, 3-year averages 1943 to 1945. Bottom line, 3-year averages 1913 to 1915.

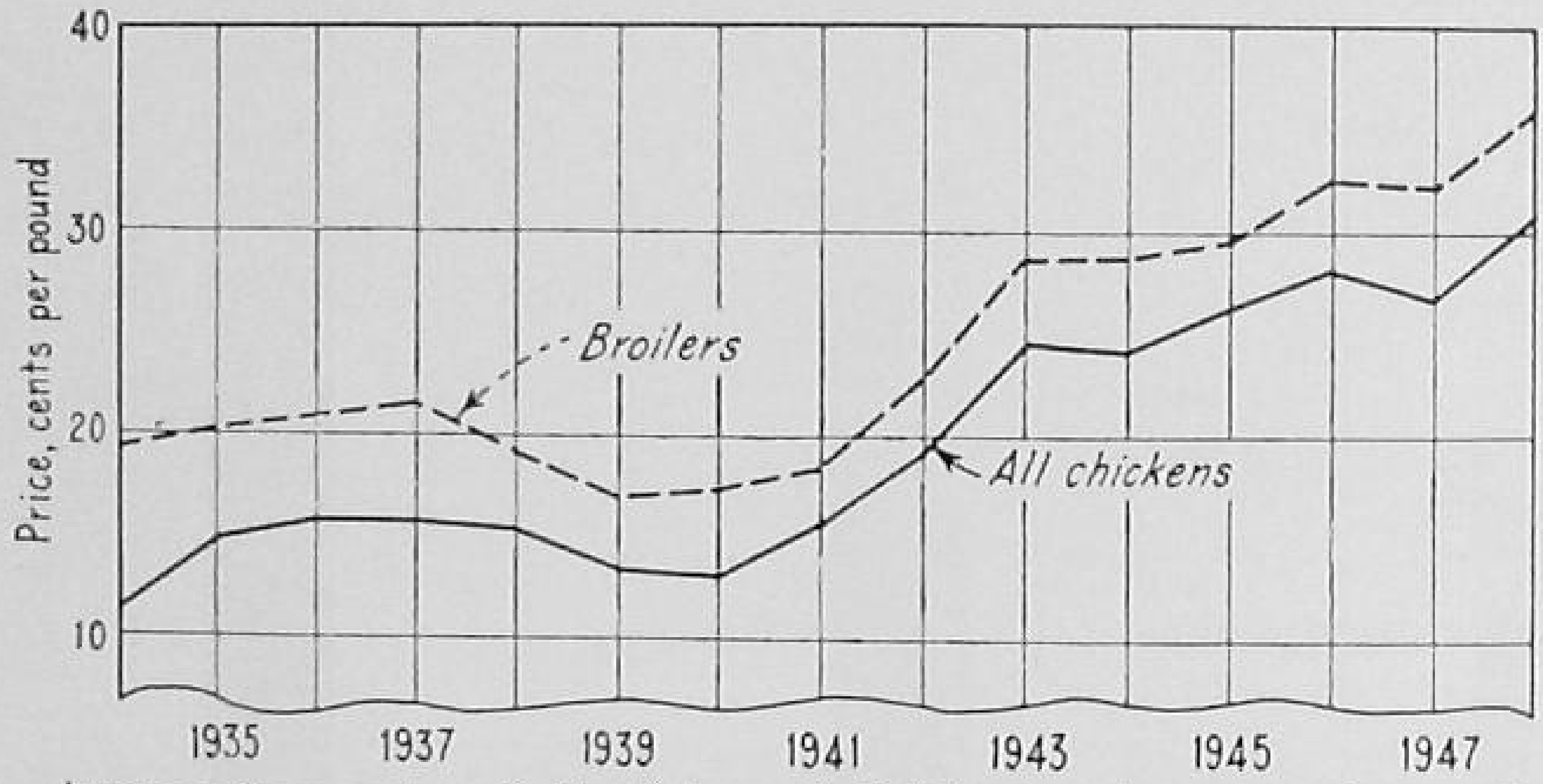

FIG. 244. Average farm price of all chickens (solid line) and average farm price of commercial broilers (dash line), 1934 to 1948.

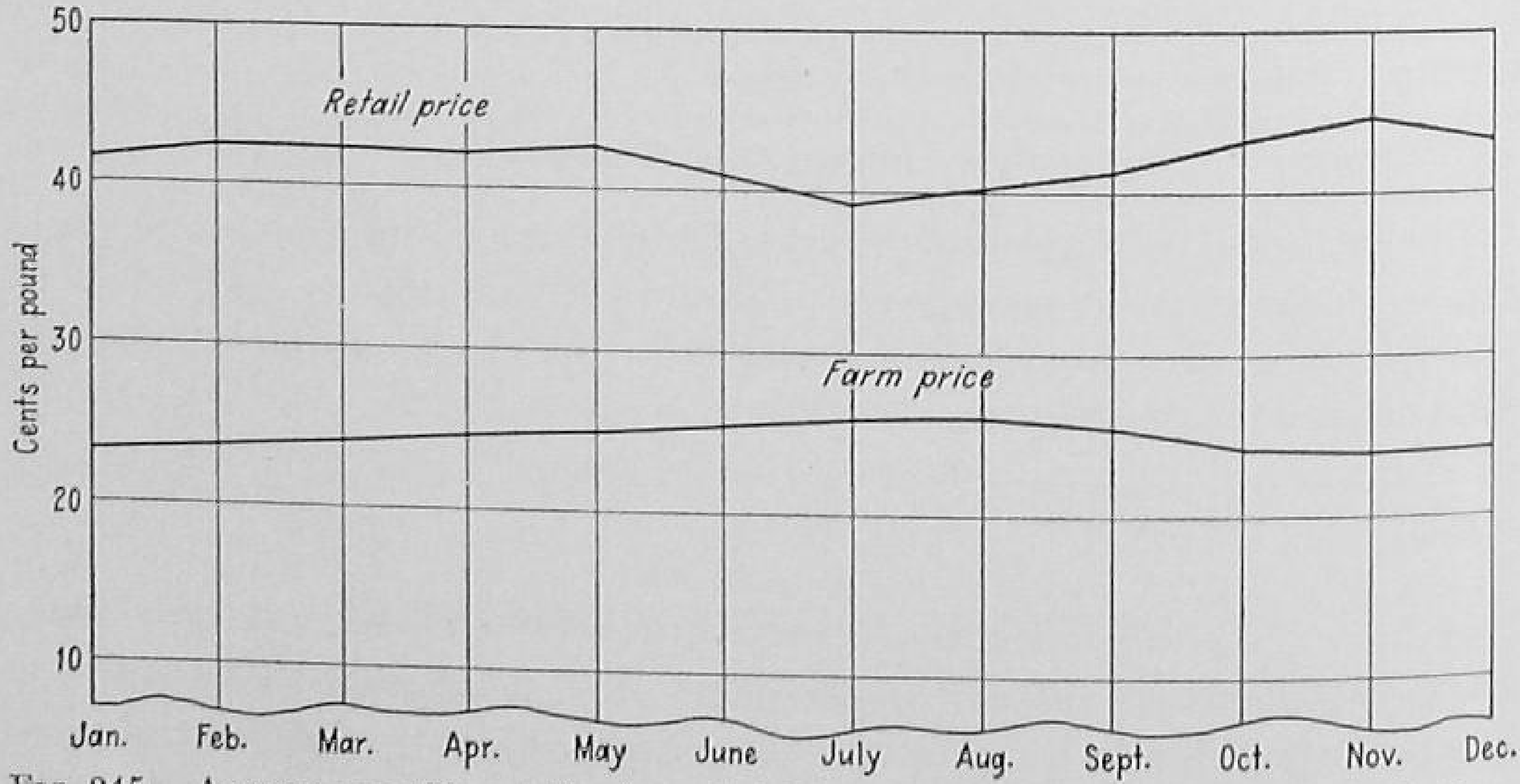

FIG. 245. Average monthly retail prices of chickens per pound and average monthly farm prices per pound, 1943 to 1945.

roasters has an effect on price. Still another factor affecting the price of poultry at certain seasons of the year is the volume of poultry in storage.

Prices are usually somewhat higher from June to September than during other months of the year, as shown in Fig. 243, which also shows the great differences in average monthly prices during 1943 to 1945 as compared with 1913 to 1915.

That broiler prices have nearly always been considerably higher than the prices of other chickens is indicated in Fig. 244. During recent years, however, the per cent increase of broiler prices over the prices of other chickens has not been so great as in the period of the early development of the broiler industry. As a matter of fact, there have been times recently when broiler prices have been lower than fowl prices.

The yearly average 1943 to 1945 prices, in cents per pound, of farm-raised chickens and broilers by regions were as follows:

	North Atlantic	South Atlantic	East North Central	West North Central	East South Central	West South Central	Moun-tain	Pacific
Farm-raised chickens...	28.9	28.0	24.8	22.0	24.8	23.5	24.2	27.1
Broilers...............	29.0	28.8	28.3	29.0	31.5	29.7	....	30.3

Mention has already been made concerning the producer's share of the consumer's dollar spent for chickens. The relative difference by months between the average farm price and the average retail price of chickens during 1943 to 1945 is shown in Fig. 245.

POULTRY-CONSUMPTION FACTORS

Poultry meat is a good source of protein, iron, and phosphorus, and there are appreciable quantities of vitamin D in chicken fat and liver. Chicken meat is a moderately good source of thiamine, a vitamin that tends to maintain the appetite and preserve the health of nervous tissue. Chicken meat supplies humans with their nicotinic-acid requirements to a relatively greater extent than many other food products.

The fat, skin, and giblets are consumed along with the lean meat, thus making chicken meat relatively more complete nutritionally than some of the red meats. The relatively small amount of connective tissue in chicken meat is another of its outstanding characteristics, thus making for tenderness and ease of digestibility. Furthermore, most people the world over like chicken meat because it is so palatable.

The chemical composition of the edible portions of chickens is given in Table 55.

TABLE 55. CHEMICAL COMPOSITION IN PER CENT OF EDIBLE PORTIONS OF CHICKENS (H. M. Harshaw, 1942)

Portion	Protein	Fat	Ash	Water
Breast muscle, males	23.5	1.12	1.11	74.6
Leg muscle, males	20.1	4.39	1.05	74.5
Remaining edible portion, males	17.3	24.10	0.79	57.6
Total edible portion, males	19.9	10.90	0.97	68.3
Total edible portion, females	19.3	11.90	1.09	65.8
Total edible portion, capons	18.7	11.90	1.03	66.2

The trend in the per capita consumption of chicken meat in the United States from 1910 to 1947 is shown in Fig. 246. The effect of the Second World War on the consumption of chicken is quite apparent, the marked increase during this period being due largely to the relative shortage of red meats for civilian use. It seems highly probable that

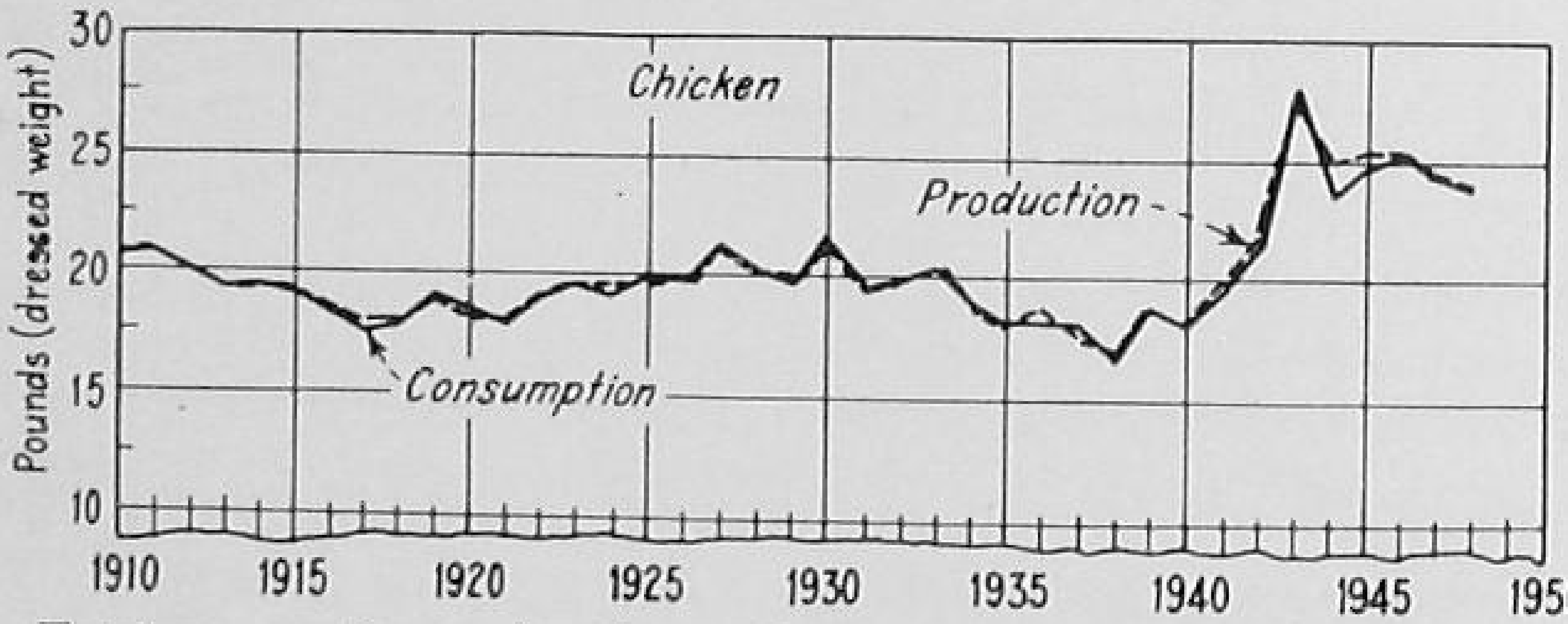

FIG. 246. Total per capita production and per capita consumption of chicken, United States, 1910 to 1947. The consumption during 1941 to 1945 (Second World War) applies to civilian consumption only.

increased production of fresh-killed, cut-up chicken has been an important factor in the expansion of outlets for and increasing the consumption of chicken meat during recent years. The level of family income is an important factor affecting purchases of poultry meat in various forms.

Imports and Exports. The United States imports and exports relatively small quantities of poultry, the largest importations being from Canada.

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CHAPTER 14

ECONOMICS OF PRODUCTION

With respect to the production of eggs and chicken meat, there are five principal enterprises that deserve consideration from the standpoint of costs of production and returns secured therefrom. These five enterprises are: (1) laying-pullet-replacement production, (2) market-egg production, (3) hatching-egg production, (4) broiler production, and (5) baby-chick production. During recent years, each of these enterprises has become specialized to a greater or less degree in some parts of the United States, notwithstanding the fact that most of the eggs and chicken meat are produced on general farms.

In order to secure satisfactory returns from any one of these enterprises, the producer must have some knowledge of the more important factors affecting returns and he must be a proficient manager capable of taking advantage of every opportunity to secure increased returns from his enterprise. A firsthand knowledge of the business and a high degree of managerial ability are two of the most important requisites for success.

LAYING-PULLET-REPLACEMENT PRODUCTION

Most farmers and commercial poultrymen, excluding broiler producers, purchase chicks for the purpose of raising pullets to replace all or a considerable portion of the laying flock. During recent years there has been an increased tendency to buy "sexed" pullet chicks, the sex of the chicks having been determined at the hatchery by the vent method or by down color among chicks secured from sex-linked crosses. When "straight-run" chicks (sexes not separated) are purchased, the cockerels are usually disposed of at broiler age, especially in the case of White Leghorns, or are later sold as fryers or roasters. The cockerels are really a by-product of the rearing enterprise because the primary objective is raising pullets for laying purposes.

The data in Table 56, dealing with the cost of raising pullets, pertain to 111 poultry farms in New York during 1940 to 1941. White Leghorn pullets were raised on 71 farms, an average of 1,249 pullets being raised per farm. General-purpose pullets were raised on 40 farms, an average of 1,044 pullets being raised per farm.

The data in Table 56 show that the cost of feed, chicks, and labor amounted to about 85 per cent of the total cost of raising pullets.

Table 56. Cost of Raising Pullets on 111 Farms in New York, 1940 to 1941 (L. B. Darrah, 1943)

Item	Value per pullet		Per cent of total	
	White Leghorns	General-purpose breeds	White Leghorns	General-purpose breeds
Costs:				
Feed	$0.60	$0.85	44.0	49.3
Chicks	0.32	0.34	23.3	19.6
Labor	0.24	0.28	18.0	16.1
Horse labor, tractor, truck	0.03	0.03	2.2	1.9
Overhead[a]	0.12	0.15	8.4	8.8
All other costs[b]	0.05	0.07	4.1	4.3
Total	$1.36	$1.72	100.0	100.0
Returns, other than pullets raised:				
Cockerels eaten and sold	$0.20	$0.40	66.8	74.1
Cockerels kept or inventoried	0.08	0.12	28.3	21.2
Manure	0.01	0.02	3.4	4.1
All other returns	0.01	0.00	1.5	0.6
Total	$0.30	$0.54	100.0	100.0
Net cost per pullet	$1.06	$1.18		

[a] Includes use of land, buildings and equipment, and interest.
[b] Includes litter, fuel, disinfectants, and similar items.

The difference in cost in raising White Leghorn and general-purpose pullets indicated in Table 56 is due almost entirely to the increased feed consumption of the general-purpose birds over the White Leghorns. On these 111 New York farms, the pounds of feed consumed per White Leghorn pullet raised averaged 27.6 as compared with an average of 37.4 for general-purpose pullets. The difference in returns are due largely to the greater value of general-purpose cockerels sold and eaten over the White Leghorn cockerels. The general-purpose cockerels weighed more at selling time, and the price per pound was over 3 cents more than for White Leghorn cockerels.

The returns for labor per pullet and per hour of labor were not determined for White Leghorns and general-purpose pullets separately. All pullets raised were valued at $1.39 per pullet, and on this basis the labor returns were as follows:

Average value of pullets	$1.39
Average net cost per pullet	1.10
Gain per pullet	$0.29
Return for labor per pullet	$0.55
Return per hour of labor	$0.86

Observations were made concerning the relative cost of raising straight-run versus sexed pullets on 80 farms in New York during 1940 to 1941. Pertinent data are given herewith:

Item	Straight-run chicks		Sexed-pullet chicks	
	White Leghorns	General-purpose breeds	White Leghorns	General-purpose breeds
Feed consumed per bird, lb	31.0	39.2	23.1	31.4
Labor per pullet raised, min	38.5	59.2	32.4	34.8
Mortality, per cent	18.4	16.6	12.2	8.6
Costs per bird	$1.49	$1.89	$1.19	$1.37
Returns per bird, other than pullets	0.47	0.93	0.04	0.05
Net cost per pullet	$1.02	$0.96	$1.15	$1.32

The net cost of raising White Leghorn pullets from straight-run chicks was 13 cents per bird less than the net cost of raising White Leghorn pullets from sexed-pullet chicks. The net cost of raising "straight-run" general-purpose pullets was 36 cents per bird less than the net cost of raising "sexed" general-purpose pullets.

In the case of both the White Leghorns and the general-purpose breeds, the sexed-pullet chickens consumed less feed because of the absence of cockerels, required less labor per bird, had relatively less mortality, and therefore cost less to raise than the straight-run chickens. On the other hand, the returns from cockerels among the straight-run flocks more than offset the lower costs of raising sexed pullets, so that the net cost per pullet raised in the straight-run flocks was less than the net cost per pullet raised in the sexed-pullet flocks.

Data pertaining to the cost of raising 97 farm-replacement flocks, averaging 423 chicks started per flock, in central Indiana in 1946 are given in Table 57.

With respect to these 97 central Indiana replacement flocks in 1946, the net returns per farm averaged $62, the total labor returns per farm averaged $179, the labor returns per hour averaged $1.18, the labor returns per 100 chicks started averaged $42, the labor returns per pullet saved averaged 95 cents, and the cost per pullet averaged $1.55.

The cost of feed, chicks, and labor amounted to 86 per cent of the total flock-replacement costs. Since the cost of feed amounted to 48 per cent of the total costs, it is interesting to note that the gross returns per $100 feed cost averaged $260. The net returns per 100 chicks started averaged $15.

TABLE 57. COST OF RAISING 97 FARM-REPLACEMENT FLOCKS IN CENTRAL INDIANA, 1946
(H. A. Johnson, L. S. Robertson, and J. W. Sicer, 1948)

Item	Per farm	Per cent
Costs:		
Feed	$241	48
Chicks	76	15
Labor	117	23
General expenses[a]	19	4
Overhead[b]	47	9
Miscellaneous	4	1
Total	$504	100
Returns:		
Pullets	$347	61
Meat birds eaten and sold	214	38
Manure	5	1
Total	$566	100

[a] Fuel, litter, electricity, and disinfectants.
[b] Interest on flock investment, depreciation, and repairs.

There were 25 White Leghorn flocks and 72 general-purpose flocks. When each of these groups was divided into small and large flocks, respectively, the labor returns per hour were found to be as follows:

	White Leghorn flocks		General-purpose flocks	
	Small	Large	Small	Large
No. of chicks started per flock	305	664	267	584
Labor returns per hour	$0.96	$1.98	$0.82	$1.44

These data show the advantage of raising relatively large flocks over small flocks.

In Table 58 data are presented pertaining to various production factors, costs, and returns in raising commercial flocks of pullets to 6 months of age in California, the figures given being averages for the 8-year period, 1941 to 1948. Some of the poultrymen purchased straight-run chicks only and some purchased pullet chicks only. For each of these two groups of chicks, the net rearing cost per pullet to 6 months of age is given at the foot of the table.

In connection with these California data, it is interesting to note that the cost of feed amounted to over 56 per cent of the total costs of raising

pullets to 6 months of age. During the 8-year period the average price of feed was $3.55 per 100 lb. In 1941, the price of feed was $2.07 per 100 lb., and the cost of feed amounted to slightly over 57 per cent of the total costs of raising pullets to 6 months of age. In 1948, the price of feed was $5.16 per 100 lb., and the cost of feed amounted to slightly over

TABLE 58. PRODUCTION FACTORS, COSTS, AND RETURNS IN RAISING PULLETS TO 6 MONTHS OF AGE IN CALIFORNIA, 1941 TO 1948
(L. D. Sanborn and A. D. Reed, 1949)

Production factors:	
Birds raised to 6 months, per cent	60.7
Birds sold, per cent	26.3
Birds died and lost, per cent	13.0
Feed consumed per pullet to 6 months, lb	30.7
Price of feed per 100 lb	$3.55
Cost per 6-months' pullet raised:	
Feed	$1.11
Chicks	0.38
Operator's and family labor	0.33
Hired labor	0.06
Litter, fuel, and miscellaneous items	0.08
Total, except interest and depreciation	$1.96
Returns per 6-months' pullet raised:	
Cockerels and pullets sold	$0.32
Eggs sold	0.14
Miscellaneous	0.03
Inventory credit[a]	0.09
Total	$0.58
Net cost per 6-months' pullet raised	$1.38
Net cost per 6-months' pullet raised (straight-run)	$1.23
Net cost per 6-months' pullet raised (sexed pullets)	$1.47

[a] Net inventory credit for birds under 6 months of age.

60 per cent of the total costs of raising pullets to 6 months of age. It should be kept in mind, however, that interest and depreciation were not included in determining total costs. Had these items been included, the percentages given above would have been reduced slightly. It is quite obvious that when feed prices are relatively high, superior quality chicks and efficient flock management are of paramount importance.

MARKET-EGG PRODUCTION

The economic returns secured from the laying flock kept primarily for the production of market eggs are affected by such factors as the average egg production per bird during the laying year, the amount of laying-flock mortality, the proportion of pullets to older birds in the flock, the extent of culling practiced, the relative number of eggs produced during

the fall months when egg prices are relatively high, the size of the laying flock, management efficiency, the cost of feed, and the price of eggs.

The poultryman has very little control over the cost of feed or the price of eggs. If he is able to produce or buy at wholesale prices the bulk of the feed used by the laying flock and if he can sell his eggs at retail prices, he has a distinct advantage over the poultryman who buys his feed at retail prices and sells his eggs at wholesale prices.

TABLE 59. EACH ITEM OF RETURNS AS A PERCENTAGE OF TOTAL RETURNS AND EACH ITEM OF COST AS A PERCENTAGE OF TOTAL COST OF PRODUCING EGGS

Item	California[a] 20-year average 1929 to 1948	Central Indiana[b] 1945 to 1946	New Hampshire[c] 1942 to 1945
Returns:			
Market-egg sales	82.8	64.7	37.8
Hatching-egg sales	......	.....	28.2
Meat-bird sales	13.2	33.2	23.9
Baby-chick sales	......	.....	7.6
Miscellaneous sales	2.7	.....	2.5
Value of manure	......	0.7	
Inventory increase	1.3	1.4	
Total	100.0	100.0	100.0
Costs:			
Feed	59.0	53.3	63.8
Labor	20.4	27.8	8.4[d]
Hatching eggs	......	.....	6.0
Baby chicks	7.7	5.6	1.9
General expenses	......	2.4	6.2
Overhead	7.5	7.6	4.2
Miscellaneous	5.4[e]	3.2	9.5
Total	100.0	100.0	100.0

[a,b,c] For sources of data, see literature references at end of chapter under the following names: (a) L. D. Sanborn and A. D. Reed, 1949; (b) H. A. Johnson, L. S. Robertson, and J. W. Sicer, 1948; (c) M. F. Abell, 1947.

[d] Hired labor only.

[e] Includes general expenses.

Returns and Costs. Before discussing the effect of the various factors mentioned above on economic returns from the laying flock, it is well to consider the items of returns and costs in market-egg production. Data pertaining to these items are given in Table 59 for California, central Indiana, and New Hampshire.

The data in Table 59 show that market eggs contributed most toward the returns secured from the flock. In California, eggs contributed more

than six times as much as meat birds and in central Indiana almost twice as much. In New Hampshire, the returns from hatching eggs were only slightly less than the returns from market eggs, but the returns from market and hatching eggs were almost three times as much as the returns from meat birds.

With respect to costs of egg production, the data in Table 59 show that the feed cost is by far the most important cost item. The price of feed not only varies from year to year but also from time to time within a year. During recent years, the Federal government's policy of supporting grain prices has resulted in the maintenance of considerably higher price levels than prevailed prior to the adoption of this policy. Market-egg producers should realize that when feed prices are relatively high it is most important to practice efficient flock management, keep mortality at a minimum, have a high percentage of pullets in the laying flock, and cull the flock rigidly according to the laying performance of the members of the flock.

Mortality. Dead birds yield no returns to the producer, except possibly as fertilizer. The most costly age at which death occurs in pullets is

TABLE 60. RELATIONSHIP BETWEEN MORTALITY AND LABOR INCOME PER BIRD, NEW HAMPSHIRE, 1942 TO 1945, AND SOUTH CAROLINA, 1936 TO 1946
(M. F. Abell, 1947, and P. H. Gooding, 1948)

Mortality, Per Cent	Labor Income per Bird
New Hampshire	
4.4	$3.99
6.8	3.08
9.9	2.73
17.9	2.29
South Carolina	
Under 20	$2.52
20 to 30	1.41
Over 30	1.18

just prior to commencement of laying. The effect of mortality on labor income per bird is shown in Table 60 for laying flocks in New Hampshire and South Carolina.

Every market-egg producer owes it to himself to do everything possible to keep laying-flock mortality at a minimum. Rigid culling of the flock, especially during the late spring and early summer months, reduces the amount of mortality that would otherwise occur in most flocks. It has been demonstrated that, in the majority of cases, rate of laying decreases for some time prior to death. Many of these birds are still in good market condition, and their economic value could be salvaged by culling them from the flock and marketing them.

Proportion of Pullets in Laying Flock. Egg production in any unculled group of birds usually declines from year to year. That is why it long since became an established practice to keep a laying flock comprised of about two-thirds pullets and one-third yearling hens. These yearling hens were the best producers during the first laying year among the pullets housed. More recently, however, it has been shown that flocks containing from 75 to 100 per cent pullets are more profitable than flocks containing a smaller proportion of pullets. Appropriate data are given in Table 61 pertaining to flocks in central Indiana.

TABLE 61. RELATIONSHIP BETWEEN PROPORTION OF PULLETS IN LAYING FLOCK AND VARIOUS FACTORS, INCLUDING LABOR INCOME PER 100 BIRDS, CENTRAL INDIANA, 1945 TO 1946
(H. A. Johnson, L. S. Robertson, and J. W. Sicer, 1947)

Item	Per cent pullets in laying flock		
	0 to 67	68 to 93	100
Average proportion of pullets	56	78	100
Egg production per bird	140	163	158
Feed consumed per bird, lb.	105	100	103
Mortality, per cent	13	10	12
Labor income per 100 birds	$2	$111	$83

With respect to the proper proportion of pullets to have in the laying flock, market-egg producers should keep in mind the relatively higher costs of replacing the whole laying flock each year as compared with the costs of replacing a part of the flock each year. In spite of this difference in replacement costs, many commercial-egg producers maintain laying flocks from year to year composed of pullets entirely. In the Middle West, where avian tuberculosis is still a problem, flocks consisting entirely of pullets would be advantageous.

Fall Egg Production. Since egg prices are relatively high during the late summer and early fall months, it is very desirable to secure good egg production during these months. This can be accomplished more readily by flocks containing a relatively high proportion of pullets in the flock than by flocks containing a relatively low proportion of pullets in the flock. This is clearly shown by the data in Table 62 pertaining to flocks in Washington state.

The data in Table 62 show that among Washington flocks in 1948, flocks containing an average of 93 per cent pullets produced a larger labor income per bird than flocks containing relatively fewer pullets per flock. This resulted from a higher average egg production for the year

Table 62. Relationship between Labor Income per Bird and Various Production Factors, Washington, 1948
(A. J. Cagle, 1949)

Item	Labor income per bird			
	Under $1.95	$1.95 to $2.94	$2.95 to $3.94	Over $3.94
Average labor income per bird, dollars	1.12	2.46	3 46	4.45
Egg production per bird	177	189	209	229
Pullets in flock, per cent	71	71	84	93
Rate of lay during Oct., Nov., Dec., per cent	51	59	63	66

and a higher rate of lay during October, November, and December by the 93 per cent pullet flocks than by the other flocks.

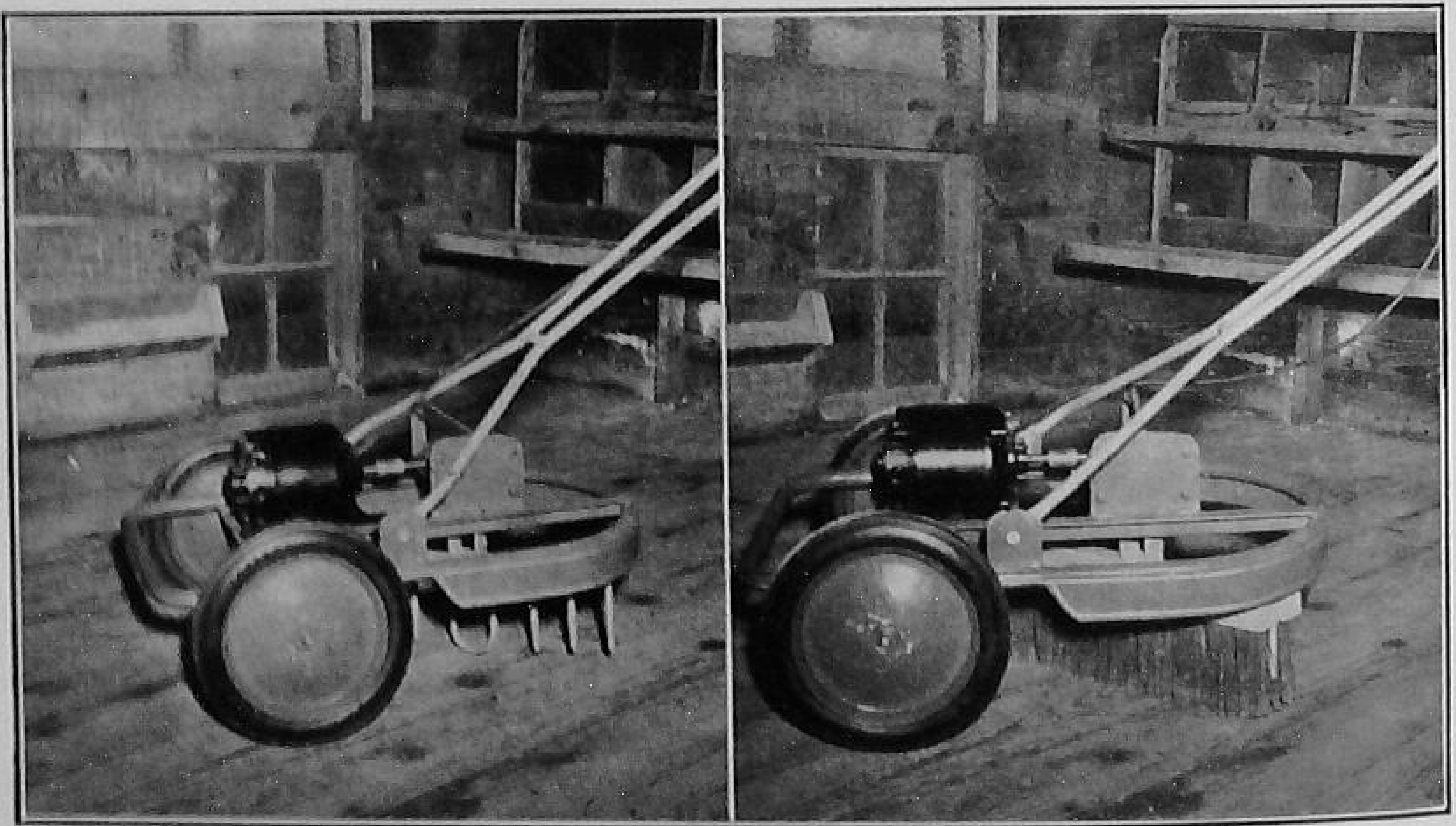

Fig. 247. Left, an electrically operated litter stirrer for keeping the litter in good condition. Right, two brooms attached for sweeping the floor. (*Dee Manufacturing Company.*)

Another illustration of the advantage of securing good fall egg production is provided by the data in Table 63 pertaining to laying flocks in South Carolina.

The data in Table 63 show that among these South Carolina flocks, those producing higher percentages of fall eggs in relation to total annual egg production also produced more eggs during the year and, therefore, yielded a relatively higher labor income per bird.

Annual Egg Production. Since it has already been indicated that the average egg production per bird by a flock is a factor of great importance

TABLE 63. RELATIONSHIP BETWEEN PERCENTAGE FALL EGG PRODUCTION (OCTOBER, NOVEMBER, AND DECEMBER) OF TOTAL ANNUAL PRODUCTION AND VARIOUS FACTORS, INCLUDING LABOR INCOME PER BIRD, SOUTH CAROLINA, 1934 TO 1938 AND 1942 TO 1946
(P. H. Gooding, 1948)

Item	Fall egg production as a percentage of total annual production			
	Under 10	10 to 14	15 to 19	Over 19
No. of flocks	65	104	105	174
Average No. of birds per flock	141	132	175	179
Average No. of eggs per bird	124	136	141	159
Feed cost per bird	$2.63	$2.37	$2.52	$3.05
Investment per bird	$2.53	$2.60	$2.62	$3.33
Other expenses per bird	$0.45	$0.42	$0.41	$0.67
Labor income per bird	$1.36	$1.58	$1.59	$2.12

in determining economic returns secured in market-egg production, further data are presented in which average egg production per bird is the variable. In Table 64 data are given pertaining to the relationship between average egg production per bird and various factors, including labor income per bird, among White Leghorn and general-purpose flocks in Washington in 1948.

TABLE 64. RELATIONSHIP BETWEEN EGG PRODUCTION PER BIRD AND VARIOUS FACTORS, INCLUDING LABOR INCOME PER BIRD, WASHINGTON, 1948
(A. J. Cagle, 1949)

Item	Range in egg production per bird		
	Under 194	195 to 214	Over 214
Average egg production per bird	172	205	234
Mortality, per cent	12	11	10
Pullets in flock, per cent	64	87	87
Rate of lay during Oct., Nov., Dec., per cent	50	63	64
Feed cost per bird, dollars	5.15	5.33	5.43
Feed cost per dozen eggs, cents	36.8	32.6	28.1
Labor income per bird, dollars	1.75	2.74	4.21

The data in Table 64 are interesting from several standpoints. Among the three groups of birds according to average egg production per bird, there was slightly less mortality as average egg production increased, although the difference in mortality is probably not significant. The higher rate of lay during the fall months between the first and second

groups was undoubtedly a factor affecting the difference in labor income per bird, but this was not a factor when the second and third groups are compared.

Since the greater the feed intake per bird as egg production increases, it is to be expected that feed costs per bird would be higher for the second over the first group and for the third over the second group. On the other hand, since the number of pounds of feed consumed per dozen eggs produced decreases as egg production increases, the feed cost per dozen eggs produced decreased progressively from the first to the third group.

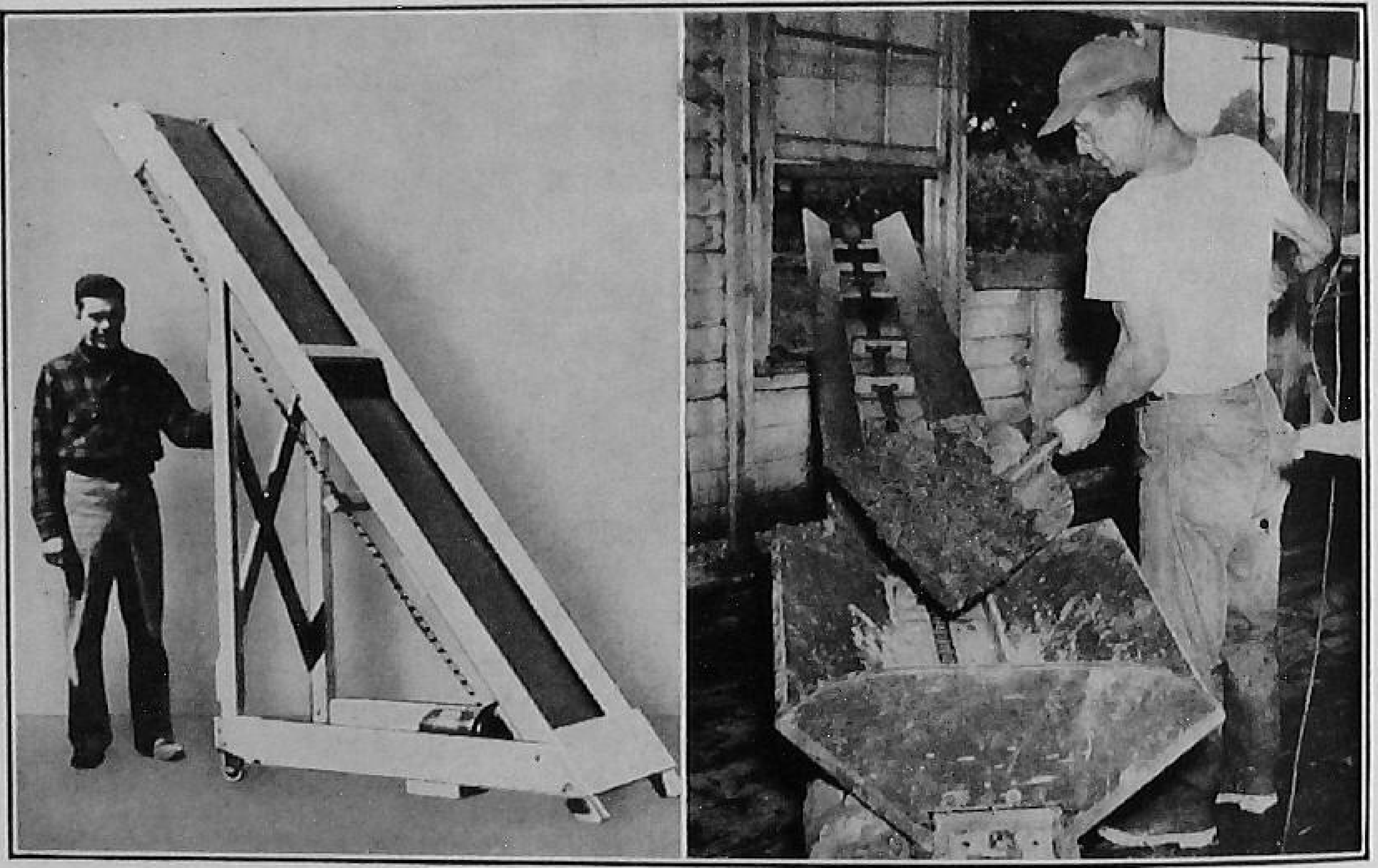

FIG. 248. Left, a bag booster. (*Burrows Equipment Company.*) Right, cleaning out the laying house on G. Parker's farm in New Jersey is made easier by using this 16-ft. conveyor, which conveys the litter to the manure spreader outside the house. (*N.J. Dept. Agr.*)

The principal factor determining the difference in labor income per bird among the three groups was the difference in average egg production per bird.

All market-egg producers should keep in mind the fact that the feed cost per dozen eggs is affected by the price of feed, the amount of mortality at different periods of the laying year, the percentage of the birds culled at different periods of the laying year, as well as by the average egg production during the year.

The data in Table 65 deal with the relationship between egg production per bird and certain factors, in addition to those already considered, for laying flocks in Missouri.

Among other things in connection with the data in Table 65, it is interesting to note that the per cent of the flock culled and died was

relatively lower as egg production per bird increased. It is also interesting to note that as egg production per bird increased, egg income as a per cent of total poultry income tended to increase, partly because the price of eggs sold per dozen tended to increase: high producers lay more eggs in the fall months.

The income over feed cost per dozen eggs, egg income per bird, and total income per bird all tended to increase as average egg production

TABLE 65. RELATIONSHIP BETWEEN EGG PRODUCTION PER BIRD AND VARIOUS INCOME, COST, AND OTHER FACTORS, MISSOURI, 1934 TO 1945
(E. B. Winner, H. L. Kempster, and T. J. Joule, 1948)

Item	Range in egg production per bird					
	Under 101	101 to 125	126 to 150	151 to 175	176 to 200	Over 200
Number of flocks	81	274	487	428	229	85
Fall as per cent of total production:						
White Leghorns	10.0	13.1	13.4	15.8	17.4	19.1
General-purpose breeds	14.2	14.9	16.3	17.7	19.4	21.5
Per cent of flock culled and died	45.0	45.0	42.0	39.0	32.0	27.0
Egg income as per cent of total income	73.0	77.0	79.0	82.0	81.0	87.0
Price of eggs sold per dozen, cents	19	19	22	23	24	23
Feed cost per dozen, cents	17	15	16	15	15	13
Income per dozen over feed cost, cents	2	4	6	8	9	10
Egg income per bird, dollars	1.38	1.93	2.45	3.03	3.69	3.77
Meat income per bird, dollars	0.50	0.56	0.64	0.65	0.84	0.56
Change in inventory per bird, dollars	−0.01	−0.03	−0.01	0.03	0.15	0.12
Total income per bird, dollars	1.87	2.46	3.08	3.71	4.68	4.45
Production costs per bird, dollars	1.54	1.90	2.23	2.41	2.79	2.61
Labor income per bird, dollars	0.33	0.56	0.85	1.30	1.89	1.84
Total capital investment per bird, dollars	2.52	2.92	3.00	2.90	3.09	2.96
Per cent return on capital investment	13.0	19.0	29.0	45.0	61.0	62.0
Years to repay capital investment	7.7	5.3	3.4	2.2	1.6	1.6

per bird increased, whereas production costs per bird tended to decrease. It follows, therefore, that labor income per bird tended to increase as average egg production per bird increased.

It is particularly interesting to note in connection with the data in Table 65 that flocks averaging 176 or more eggs per bird would require only 1.6 years to repay capital investment as compared with 7.7 years for flocks averaging less than 101 eggs per bird.

Size of Enterprise. On most farms throughout the Middle West, market-egg production is a side-line enterprise of the general farming operations. On many farms with small-sized flocks, the care of the birds

and the gathering and marketing of eggs are left pretty much in the hands of women and children. It is only when egg receipts account for a reasonable share of the total farm income that the farmer himself begins to take an interest in the market-egg-production enterprise. From then on, greater interest is taken in factors affecting returns, and steps are taken to improve conditions by securing better chicks, providing better houses, feeding better balanced rations, properly cooling the eggs to preserve quality, and marketing them more frequently. In many cases the laying flock is increased in size. With these things in mind, the data in Table 66, pertaining to central Indiana flocks, should be of interest.

TABLE 66. RELATIONSHIP BETWEEN SIZE OF FLOCK AND VARIOUS FACTORS, INCLUDING LABOR INCOME PER HOUR AND PER BIRD, CENTRAL INDIANA, 1945 TO 1946 (H. A. Johnson, L. S. Robertson, and J. W. Sicer, 1948)

Item	Range in No. of layers per flock		
	Less than 121	121 to 240	Over 240
No. of birds per flock	87	170	323
Labor per bird, hours	3.5	2.5	2.6
Per cent pullets in flock	95	91	90
Mortality, per cent	15	10	8
Feed consumed per bird, lb	108	102	88
Egg production per bird	154	148	180
Feed cost per dozen eggs, cents	23	23	16
Average price of eggs per dozen, cents	38	39	41
Labor income per hour, dollars	0.33	0.56	1.36
Labor income per bird, dollars	0.32	0.82	2.06

The data in Table 66 show that flocks of over 240 layers had less mortality, consumed fewer pounds of feed per bird, laid much better, produced eggs at less cost per dozen, and their eggs sold at a higher price per dozen than in the case of smaller sized flocks. Better quality laying stock and more efficient flock management were undoubtedly largely responsible for the flocks of over 240 layers returning more than six times the labor income per bird than the flocks of less than 121 eggs per bird and more than 2.5 times the labor income per bird than the flocks of from 121 to 240 layers.

In sections of the country where commercial-egg production is carried on extensively, many poultrymen desire information concerning the approximate size of flock necessary to provide a reasonable family income. The data in Table 67, pertaining to Washington laying flocks, provide information pertaining to this problem.

TABLE 67. RELATIONSHIP BETWEEN SIZE OF FLOCK AND VARIOUS FACTORS, INCLUDING LABOR INCOME PER BIRD, WASHINGTON, 1948
(A. J. Cagle, 1949)

Item	Range in No. of layers per flock			
	Under 395	395 to 594	595 to 994	Over 995
No. of birds per flock	236	478	797	1884
Egg production per bird	178	207	199	195
Mortality, per cent	8	13	10	11
Investment per bird	$2.76	$2.73	$2.72	$2.50
Labor income per bird	$1.83	$2.94	$2.72	$2.55

With respect to the data in Table 67, it is to be noted that under conditions existing in Washington in 1948, including such factors as the price of feed and the price of eggs, a flock of approximately 1,800 layers provided a labor income of slightly over $4,600 and a flock of approximately 800 layers provided a labor income of somewhat over $2,100.

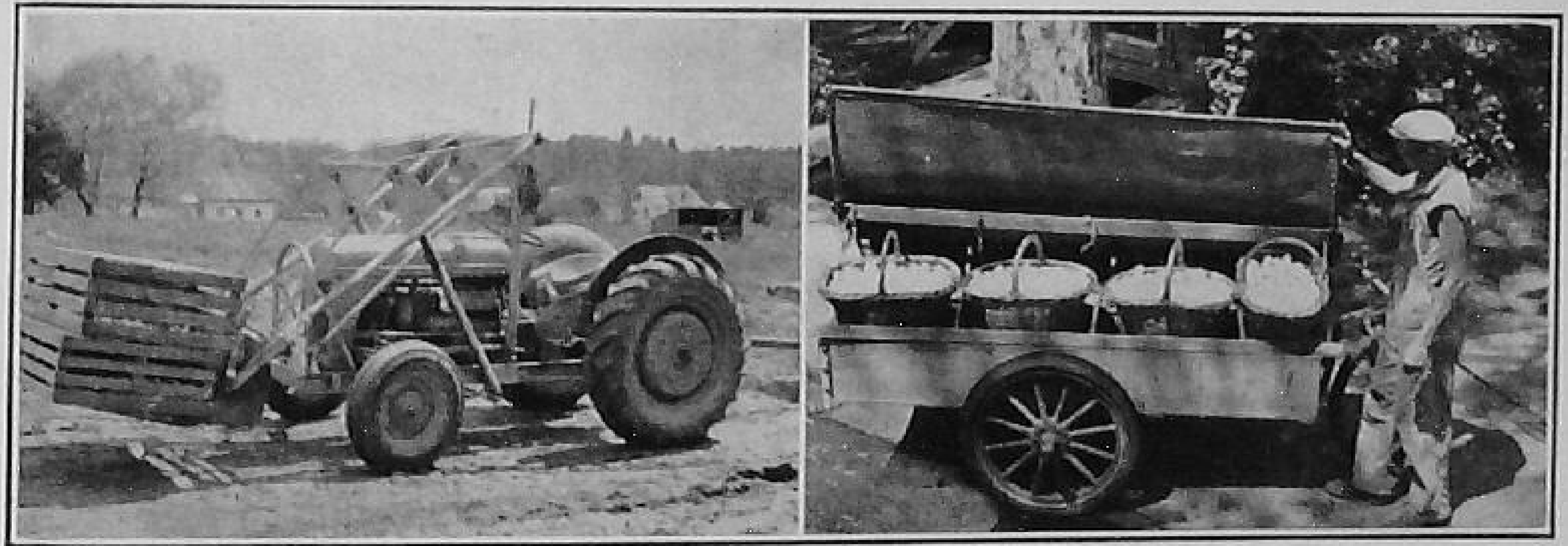

FIG. 249. Left, crates of market birds are moved easily with this hydraulic lift or loader on the poultry plant of A. Brownell in Oregon. Right, this 3-wheeled egg cart, which is pulled, is used for transporting eggs to the cooling room on the farm of G. J. Richardson in California. A canvas top protects the eggs from rain or from the intense rays of the sun. (*Pacific Poultryman.*)

Obviously, with relatively high feed prices but relatively low egg prices, more layers would be necessary to produce the same labor income per flock as indicated above.

The modern trend in building wider laying houses, some of them three or four stories high, installing droppings pits instead of boards, using overhead carriers for delivering feed to the different pens and for gathering eggs, using relatively few partitions, cleaning out the houses by using conveyors to load manure on to manure spreaders outside the house or running the manure spreader through the house, and using other labor-saving facilities, as well as arranging the chore route to save steps and time, have all tended to increase efficiency of flock management and make

it possible for one man to care for a considerably larger flock than was formerly the case.

Data pertaining to the relationship between various measures of the size of the laying-flock enterprise and labor income per bird are given in Table 68 pertaining to laying flocks in New Hampshire, 1942 to 1945. It should be kept in mind that of the total poultry returns secured from

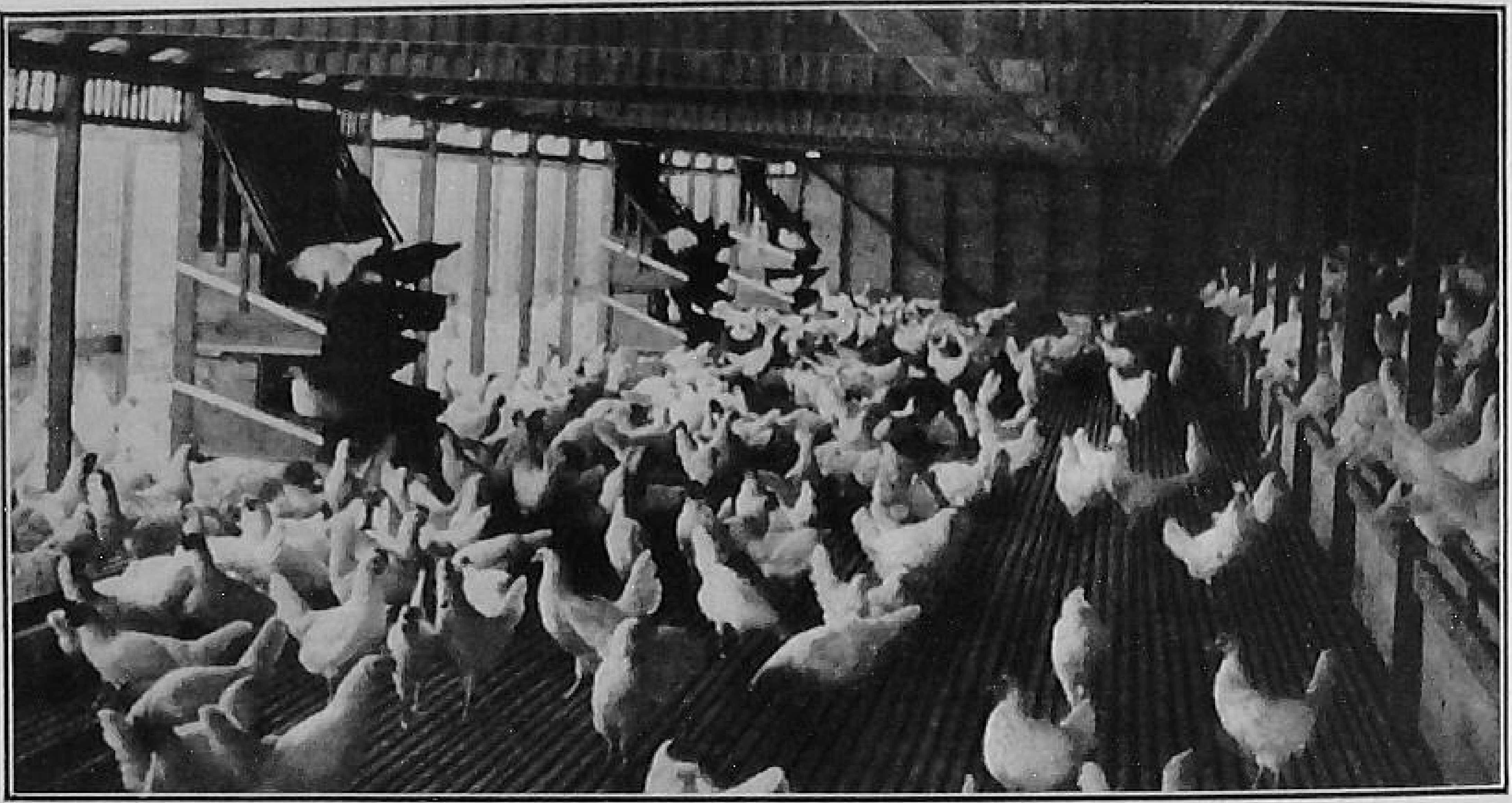

FIG. 250. Interior view of F. Welter's house in California, showing slat floors in sections, which are easily moved for cleaning out the house. (*Nulaid News*.)

these New Hampshire flocks, 37.8 per cent was secured from the sale of market eggs and 28.2 per cent from the sale of hatching eggs. Hatching-egg prices would naturally be higher than market-egg prices, but the cost of producing hatching eggs would be somewhat higher than the cost of producing market eggs.

TABLE 68. RELATIONSHIP BETWEEN VARIOUS MEASURES OF SIZE OF ENTERPRISE AND LABOR INCOME PER BIRD, NEW HAMPSHIRE, 1942 TO 1945
(M. F. Abell, 1947)

No. of layers	Labor income	Eggs per farm	Eggs per man	No. of men	Eggs per bird	Labor income per bird
708	$ 753.63	110,555	110,555	1.00	156	$1.06
736	794.68	113,169	99,113	1.14	154	1.08
876	969.64	136,733	84,148	1.62	156	1.11
1,153	1,154.24	181,242	77,345	2.34	157	1.00

The data in Table 68, based on average number of layers per flock, show that an increase from 708 to 1,153 layers per flock yielded an increase of $400.61 in labor income, in spite of the fact that the labor

income per bird was practically the same in the two flocks of different sizes. However, since 2.34 men were required to manage the 1,153-layer flocks as compared with 1 man to manage the 708-layer flocks, it is apparent that the labor income per man is less in the case of the larger sized flocks than in the case of the smaller sized flocks. Undoubtedly, in the case of the larger sized flocks, family labor was employed very largely, with relatively little hired labor. Even so, with modern labor-saving conveniences and the chore route arranged to save time and labor, it should be possible for one person to care for more than 1,153 layers. On some modern commercial market-egg-producing plants one man is able to care for considerably larger sized flocks.

Costs and Returns from Layers in Cages. In Southern California enormous numbers of birds are kept in individual laying cages rather than

TABLE 69. RELATIONSHIP BETWEEN VARIOUS PRODUCTION, COST, AND INCOME FACTORS PERTAINING TO LAYERS ON FLOOR VERSUS LAYERS IN CAGES, CALIFORNIA, 1941 TO 1948
(L. D. Sanborn and A. D. Reed, 1949)

Item	Layers on floor	Layers in cages
No. of records	142	32
Average No. of birds per flock	1,438	831
Average No. of eggs per bird	174	189
Average egg production per bird in fall	50	60
Per cent pullets	60	73
Per cent mortality	21	23
Per cent culled	72	94
Investment per bird, dollars	4.66	7.28
Hours of labor per bird	2.6	3.8
Labor cost per bird, dollars	1.61	2.29
Total cost per bird, dollars	6.76	8.60
Total income per bird, dollars	7.54	8.88
Management income per bird, dollars	0.78	0.28
Value of family labor per bird, dollars	1.27	2.11
Labor income per bird, dollars	2.05	2.39
Interest per bird, dollars	0.23	0.37
Average income per bird, dollars	2.28	2.76
Net cost per dozen eggs, cents	39.6	44.5

in laying houses. Since this practice has steadily increased during recent years, many poultrymen must believe that this method of producing market eggs is economically sound. The data in Table 69 would seem to justify the belief.

Concerning the data in Table 69, it is interesting to note that the

average annual and fall egg production was slightly better, and the per cent of pullets in the flock was higher in the cage birds than in the floor birds. The per cent of cage birds culled was considerably higher than the per cent culled in the floor birds. Also, investment per bird was much higher for cage than for floor birds. Hours of labor and labor cost per bird were higher for cage than for floor birds. Although management income per bird was 50 cents less for cage than for floor birds, the

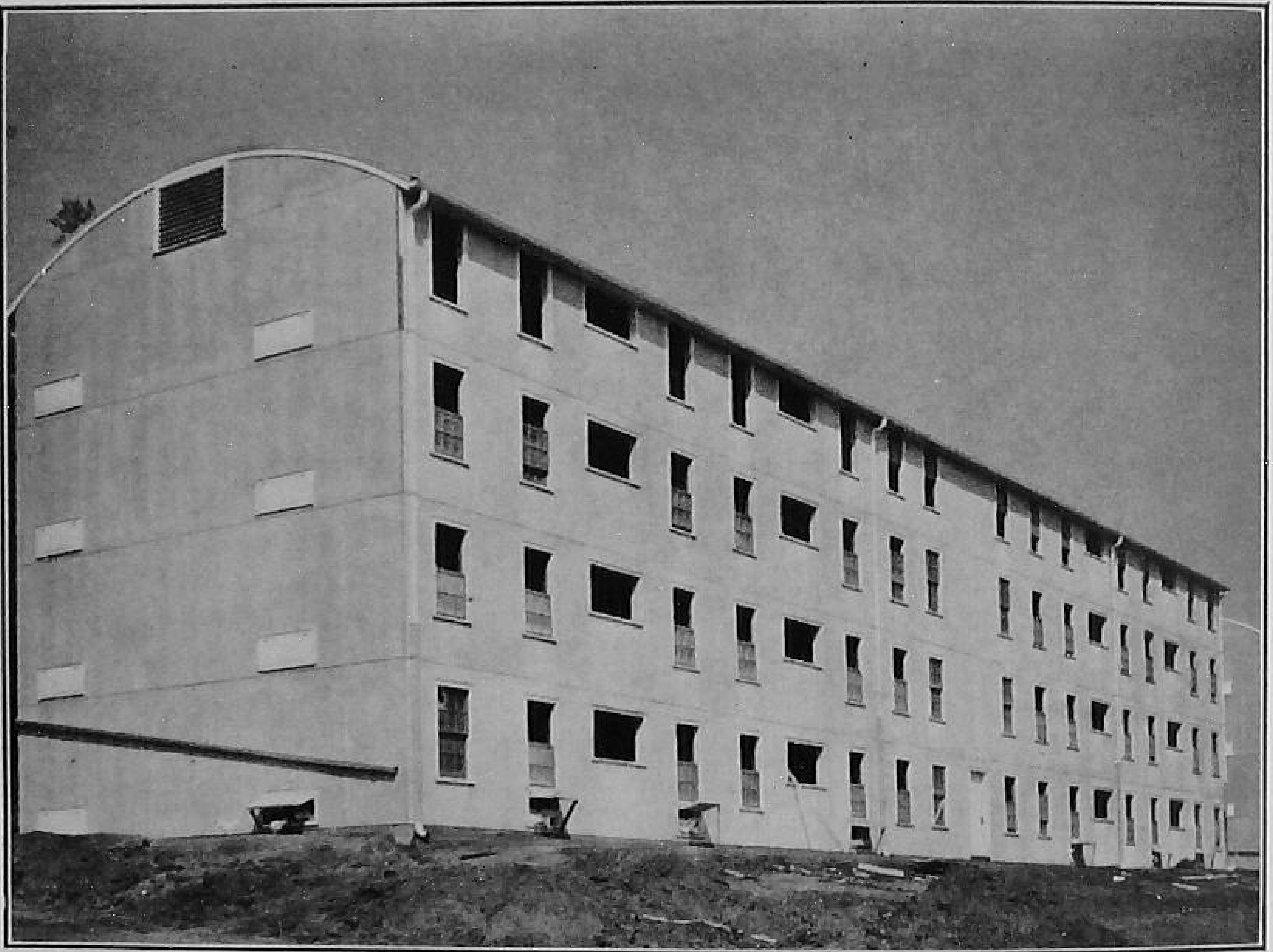

Fig. 251. One of five laying houses on the farm of A. A. Unress in Minnesota. Each house is 30 by 400 ft. and has a capacity of 7,500 birds. (*Insulite Division, Minnesota and Ontario Paper Company.*)

value of family labor per bird was 84 cents more for cage than for floor birds. The difference of 34 cents accounts for the labor income per bird of cage birds of $2.39 as compared with $2.05 for floor birds. The difference in net cost per dozen of 4.9 cents in favor of floor birds must have been offset by such factors as higher prices received for eggs and perhaps fewer dirty eggs to be cleaned.

Income in Relation to Capital Turnover. Commercial poultrymen should always keep in mind two important factors related to the amount of capital invested in the market-egg-production enterprise. The first factor is that the amount of capital invested in laying houses, egg-cooling rooms, feed-storage rooms, and other facilities must, of course, be suffi-

cient to secure satisfactory returns in egg production with maximum efficiency of operation but, at the same time, should not be in excess of actual needs; otherwise, interest on the investment, taxes, insurance, and the cost of repairs and maintenance will absorb too high a proportion of the income obtained from year to year. The second factor is that the capital investment must be sufficient to provide enough gross sales from the enterprise to give the poultryman a reasonable labor income after paying all fixed charges. One way of increasing gross sales in relation to capital investment and thereby increasing labor income in proportion to fixed charges is to keep the laying houses filled to capacity throughout the laying year.

The data in Table 70 show that the higher that receipts are as a percentage of capital investment the higher is the labor income.

TABLE 70. RELATIONSHIP BETWEEN RECEIPTS AS PERCENTAGE OF CAPITAL INVESTMENT AND LABOR INCOME, NEW HAMPSHIRE 1942–1945
(M. F. ABELL, 1947)

Average capital invested	Average receipts	Receipts as percentage of capital investment	Labor income
$11,134.11	$ 9,710.62	87.2	$1,773.44
7,043.62	7,823.43	111.1	1,822.70
8,618.40	11,987.27	139.1	3,449.36
10,078.30	23,159.15	229.7	4,129.16

Based on the returns secured from flocks in New Hampshire during 1942 to 1945 in relation to capital invested, it was found that receipts must amount to at least 75 per cent of the capital investment per year to ensure a reasonable labor income.

HATCHING-EGG PRODUCTION

The cost of producing hatching eggs is more expensive than the cost of producing market eggs.

The cost of males and their depreciation in value from the beginning to the end of the breeding season is one item of expense in producing hatching eggs as compared with producing market eggs. These males replace the same number of females that would otherwise be kept, so that somewhat fewer eggs would be produced. In the case of hatchery flocks maintained throughout the year to produce hatching eggs for "broiler" chicks, it is often necessary to maintain a reserve group of males to replace

the first group in order to secure good fertility during the summer months. The feed consumed by the males is an item to be considered. Normal mortality among males is an expense.

Mortality among the females is usually somewhat higher when they are mated with males. The selling value of females mated to males is relatively lower than the selling value of females kept for market-egg production. The hatchery flock should be fed a "breeder" mash, which is more expensive than a "laying" mash. Some of the eggs produced by hatchery flocks are not acceptable for incubation. Jumbo and small eggs, as well as those that are thin shelled or slightly misshapen, must be sold as market eggs.

Poultry breeders who carry on progeny-testing work to produce superior quality chicks require more labor in trap-nesting and record keeping than most hatchery-flock owners. The cost of pullorum testing is another item of added costs in producing hatching eggs over market eggs.

Practically no data are available on the cost of producing hatching eggs for the simple reason that at different seasons of the year market eggs are also sold. This is especially true of hatchery flocks mated during January through May for the production of eggs from which chicks for laying-flock replacements are secured. Even in the case of hatchery flocks maintained throughout the year for producing eggs for "broiler" chicks, considerable numbers of the eggs produced are sold as market eggs. This happens when there is a greatly decreased demand for "broiler" chicks.

BROILER PRODUCTION

Except for broiler production, and in a few cases capon production, chicken-meat production is largely a secondary enterprise for most farmers and commercial-market-egg producers, who are primarily interested in purchasing chicks for laying-flock-replacement purposes.

The various forms in which chicken meat is sold to consumers include broilers, fryers, roasters, capons, fowl, and cocks or stags. The last two forms include birds culled from the laying flocks and male breeding stock. Commercial-broiler production has become a highly specialized enterprise, although many of the birds produced on so-called broiler plants are fryers and roasters. Data on the economics of chicken-meat production are limited almost entirely to the so-called "broiler industry."

Proportional Broiler-production Costs. The total costs of producing broilers include feed, chicks, labor, general expenses, and overhead. The order of the relative importance of these items of cost is indicated in Table 71.

TABLE 71. EACH ITEM OF COST AS A PERCENTAGE OF THE TOTAL COST OF PRODUCING BROILERS

Cost item	Maryland[a] 1934 to 1936	Arkansas[b] 1938 to 1939	Maryland[c] 1941	Maine[d] 1944	W. Virginia[e] 1945	Delaware[f] 1946
Feed	54.3	59.6	60.4	62.9	66.7	72.9
Chicks	25.1	18.3	18.6	14.4	19.3	11.7
Labor	8.6	11.6	10.3	14.0	4.3	7.4
General[g]	6.4	6.1	5.7	3.8	5.6	5.7
Overhead[h]	5.6	4.4	5.0	4.9	4.1	2.3
Total	100.0	100.0	100.0	100.0	100.0	100.0

[abcdef] For sources of data, see literature references at end of chapter under the following names: (*a*) P. R. Poffenberger and S. H. DeVault, 1937; (*b*) W. T. Wilson and R. M. Smith, 1941; (*c*) T. J. Davies, P. R. Poffenberger, and S. H. DeVault, 1942; (*d*) A. L. Perry and G. F. Dow, 1945; (*e*) J. H. Clarke, 1949; (*f*) R. O. Bausman, 1947.

[g] Includes fuel, litter, light, water, trucking, disinfectants, drugs, and vaccination.

[h] Includes interest on investments, depreciation, taxes, insurance, and repairs.

The data in Table 71 show that the cost of feed constitutes by far the most important single cost factor in producing broilers, and that during recent years, due to higher feed prices, the percentage cost of feed has increased proportionally. It is interesting to note that the cost of feed, chicks, and labor in Maryland in 1934 to 1936 amounted to 88 per cent of the total cost and that in Delaware in 1946 the cost of these three items amounted to 92 per cent of the total cost; in the other three cases cited, the cost of these three items was between 88 and 92 per cent of the total cost. General expenses and overhead costs taken together amounted to 12 per cent of the total cost in Maryland in 1934 to 1936 and 8 per cent of the total cost in Delaware in 1946.

Cash Production Costs. Since overhead costs in broiler production are relatively stable and since they apply even when no broilers are being produced, many broiler producers are much more interested in the cash or "out-of-pocket" costs of broiler production than they are in the total costs of production. What concerns them most is what their cash costs would be for starting a batch of broilers at a given time as influenced by the price of feed, chicks, fuel, litter, and other items that must be paid for in cash plus the cost of hired labor. Data on cash production costs are given in Table 72 for Delaware in 1946 and Maryland for the production period of 1947 and the first half of 1948.

Broiler-production Returns. In highly commercial broiler-producing areas, the sale of broilers usually constitutes over 99 per cent of the returns, since less than 1 per cent of the broilers raised is consumed on

TABLE 72. CASH COST OF PRODUCING BROILERS IN DELAWARE, FEB. 1 TO SEPT. 15, 1946, AND IN MARYLAND DURING PRODUCTION PERIOD OF 1947 AND FIRST HALF OF 1948
(R. O. Bausman, 1947 and H. D. Smith, P. R. Poffenberger, and S. H. DeVault, 1949)

Cost item	Per 100 broilers		Per cent of total cost	
	Delaware	Maryland	Delaware	Maryland
Feed	$650	$589	77.0	75.0
Chicks	104	139	12.3	17.7
Hired labor[a]	40		4.7	
Fuel	14	20	1.7	2.6
Miscellaneous[b]	36	37	4.3	4.7
Total	$844	$785	100.0	100.0

[a] The cost of hired labor was not included in the Maryland data.
[b] Litter, drugs, vaccination, etc.

the premises. In many cases, no cash returns are secured from the manure produced, although West Virginia broiler producers have estimated that an average of 3.7 tons, including litter, were produced on the

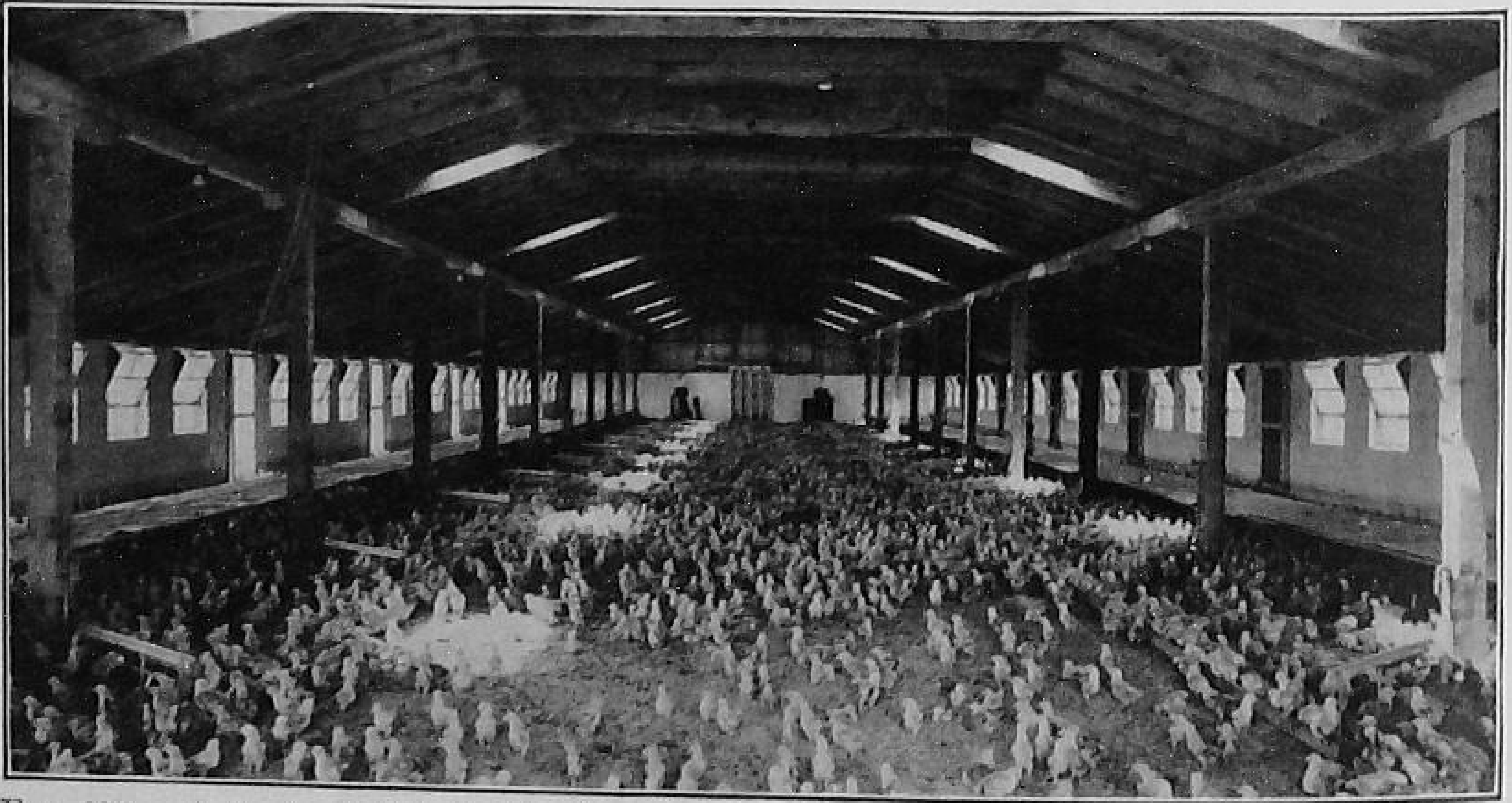

FIG. 252. A 44- by 300-ft. broiler house on L. B. Brittingham's broiler plant in Delaware. The house has a capacity of over 20,000 broilers. The skylight windows aid greatly in ventilation, especially in hot weather. (*Photograph courtesy of J. F. Gordy and New Hampshire Breeder.*)

average per 1,000 broilers. The value of the manure would depend upon its moisture content and the kind of litter used. Chicken manure has considerable value as fertilizer for crop production, and every effort should be made to use as much of it as possible for that purpose. In the case of the radiant-heat method of brooding, the moisture content of the

manure might be as low as 12 per cent, in which case it should be possible to bag and sell it to florists.

Factors Affecting Costs and Returns. For any given period and for any given batch of broilers, the price received for broilers produced and the price paid for feed, chicks, and hired labor are factors of vital importance affecting returns secured from the broiler enterprise in relation to costs of production. One inherent difficulty facing most broiler producers when they invest money in feed and chicks to raise a batch of broilers is their inability to anticipate what the price of broilers may be at the end of the 12- to 14- week growing period. The relatively handsome profits made in broiler production during the Second World War were considerably reduced during the postwar period, and it is apparent that in order to make reasonable profits in the broiler enterprise in the future, strict attention must be paid to all factors affecting efficiency of production.

Rate of Growth. Rapid rate of growth is very important in order to secure satisfactory returns in broiler production because, on the average, the faster that chickens grow the more efficiently they utilize feed, the most important item of cost in broiler production. In other words, the more rapid the growth, the less the amount of feed consumed per pound of gain in weight.

The rate at which broilers grow and, consequently, the gain in weight per unit of feed consumed are influenced not only by the inherent quality of the chicks but also by such other factors as kind of diets fed, disease, and the management of the flock, including the average floor space provided per bird.

Efficiency of Feed Utilization. Broiler producers who keep accurate records of the amount of feed consumed by their broilers and their weight at selling time can determine the average number of pounds of feed consumed per pound of broiler produced. This is useful information when considered in relation to the price of feed and the percentage that feed cost is of total broiler-production costs. Feeding poorly balanced diets, overcrowding, high mortality, and inefficient management of the flock all tend to increase the average number of pounds of feed per pound of gain in weight and thus decrease profits. The data in Tables 73, 74, and 75 show the importance of doing everything possible to promote efficient utilization of feed.

With respect to the data in Table 73, it should be noted that the three groups which consumed an average of 3.2, 3.7, and 4.3 lb. of feed, respectively, per pound of broiler produced had about the same mortality and were sold at about the same age. The profit per pound for the first of these three groups was 10.2 cents, whereas the profit per pound for the

TABLE 73. RELATIONSHIP BETWEEN EFFICIENCY OF FEED UTILIZATION AND PRODUCTION FACTORS, COSTS, AND RETURNS, MAINE, 1944
(A. L. Perry and G. F. Dow, 1945)

Item	Amount of feed per pound of broiler produced, lb.					
	Under 3.5	3.5 to 3.9	4.0 to 4.4	4.5 to 4.9	5.0 to 5.5	5.5 and over
No. of lots	32	47	105	60	85	29
No. of chicks started per lot	951	1,423	2,755	1,428	2,270	1,748
Feed consumed per pound of broiler produced, lb.	3.2	3.7	4.3	4.6	5.2	6.8
Mortality, per cent	8.8	9.5	9.7	11.9	14.7	21.0
Age sold, weeks	13.9	13.5	13.7	14.4	17.2	16.1
Weight when sold, lb.	4.5	4.0	3.8	4.0	4.1	3.8
Costs per bird, cents	87.0	87.2	88.2	98.7	112.7	126.0
Costs per pound, cents	19.4	21.9	23.2	24.9	27.2	33.5
Returns per pound, cents	29.6	29.6	29.0	28.9	29.1	29.1
Profit per pound, cents	10.2	7.7	5.8	4.0	1.9	−4.4

third of these three groups was only 5.8 cents. The extent that the number of pounds of feed consumed per pound of broiler produced is below the average weight of the birds when sold, usually the greater the profits in broiler production. The relatively high mortality of the last two groups, 5.0 to 5.5 and 5.5 and over, resulted in more pounds of feed being consumed per pound of broiler produced because it took them over

TABLE 74. RELATIONSHIP BETWEEN EFFICIENCY OF FEED UTILIZATION AND COSTS, AND NET RETURNS, DELAWARE, 1946
(R. O. Bausman, 1947)

Item	Amount of feed per pound of broiler produced, lb.		
	Under 4.5 (av. 4.2)	4.5 to 4.9 (av. 4.7)	5.0 and over (av. 5.5)
No. of lots	28	30	25
No. of chicks started per lot	14,627	11,033	14,102
Age sold, weeks	14.7	15.0	15.8
Mortality, per cent	9.6	12.5	17.6
Costs per pound, cents[a]	27.5	30.0	33.6
Costs per 1,000 broilers, dollars[a]	838.0	903.0	1,019.0
Net returns per pound, cents[b]	5.6	4.3	0.9
Net returns per 1,000 broilers, dollars[b]	177	130	38

[a] Including value of operator's labor.
[b] Total returns less total expenses, including operator's labor.

2 weeks longer than the other groups to attain approximately the same weight at selling time.

The data in Table 74 indicate that mortality may have been the principal factor responsible for the differentiation among the three groups with respect to pounds of feed per pound of broiler produced. It was found that each increase of 1 lb. of feed consumed per pound of broiler produced resulted in an average increase in cost of production of 4.8 cents per pound.

In Table 75 data are given showing the relationship between efficiency of feed utilization and the average cash cost per pound of broiler produced as well as the average profit per 1,000 chicks started based on the cash

TABLE 75. RELATIONSHIP BETWEEN EFFICIENCY OF FEED UTILIZATION, AVERAGE CASH COSTS PER POUND OF BROILER PRODUCED, AND AVERAGE PROFIT PER 1,000 BIRDS STARTED, MARYLAND, 1947 TO 1948
(H. D. Smith, P. R. Poffenberger, and S. H. DeVault, 1949)

Average amount of feed per pound of broiler produced, lb.	No. of lots produced	Average cash cost per pound of broiler produced, cents	Average profit per 1,000 birds started, dollars
3.21	29	26	212.32
3.98	335	28	165.11
4.86	65	34	36.82

costs of producing broilers. The data in Table 75 were obtained from Maryland broiler producers and are based on 429 lots, averaging 7,980 birds per lot, the number of chicks started being 3,384,880, from which 3,001,551 broilers were sold.

A more detailed analysis of the data presented in Table 75 led the authors to conclude that for each ¼-lb. increase in feed consumed per pound of broiler produced, the cash costs of production increased 1.2 cents per pound. Also, for each ¼-lb. increase in feed consumed per pound of broiler produced, the profit decreased at the rate of $36.50 per 1,000 birds started.

Age and Weight When Sold. The faster the rate of growth, the sooner are broilers ready to be marketed at any given marketable weight. By the time that a batch of broilers have attained marketable weight, most broiler producers are faced with the problem of deciding whether to keep their broilers longer in anticipation of a rise in price or whether to sell immediately in fear of a decline in price. The broiler producer must take into consideration whether his broilers are continuing to gain in weight

at that particular time and the difference in market price for broilers of different size.

Table 76 gives data pertaining to the relationship between the age of broilers when sold and their average weight, the average cash cost per pound of broiler produced, and the average profit per 1,000 birds started in the case of broilers produced in Maryland in 1947 and the first half of 1948.

TABLE 76. RELATIONSHIP BETWEEN AGE OF BROILERS WHEN SOLD, THEIR AVERAGE WEIGHT, CASH COST PER POUND OF BROILER PRODUCED, AND PROFIT PER 1,000 BIRDS STARTED, MARYLAND, 1947 TO 1948
(H. D. Smith, P. R. Poffenberger, and S. H. DeVault, 1949)

Average age when sold, weeks	No. of lots produced	Average weight per bird, lb.	Average cash cost per pound of broiler produced, cents	Average profit per 1,000 birds started, dollars
10	32	2.84	27	174.34
11	73	2.96	28	180.21
12	132	2.96	28	178.21
13	118	3.12	29	157.06
14	44	3.21	31	81.13
15	22	3.29	32	57.64
16	8	3.29	30	35.79

The data in Table 76 show that producers who sold their broilers at 10, 11, and 12 weeks of age made the greatest profit per 1,000 broilers started. It was found that, on the average, for every week's increase in age, after 12 weeks, at which broilers were sold, cash costs of production increased 0.8 cent per pound of broiler sold and profit decreased $25.50 per 1,000 birds started.

The average weight of a lot or batch of broilers at the time they are sold is a factor of great importance to all broiler producers. Naturally, it is desirable to produce as many pounds of broilers of marketable weight as possible in the shortest possible time, because broilers are sold at so much per pound, and for each week after the birds have attained suitable market weight, the pounds of feed consumed weekly per pound of gain in weekly weight increase progressively. On the other hand, the price per pound is usually higher in proportion to increase in broiler size or weight. When all costs of production are considered, including cost of chicks, general expenses, and overhead, it costs less per pound to produce broilers averaging 4 lb. than broilers averaging 2.5 lb. However, the longer that broilers are kept, the greater is the loss from mortality, and, in addition, the producer always takes a risk of a decline in prices against a possible

rise in prices. The broiler producer must also keep in mind the hazard of overcrowding and retardation in rate of growth if broilers are held too long.

The data in Table 77 throw some light on the relationship between the weight of broilers at selling time and the cash cost per pound of broiler produced and the profit per 1,000 birds started.

TABLE 77. RELATIONSHIP BETWEEN AVERAGE WEIGHT PER BROILER WHEN SOLD, CASH COST PER POUND OF BROILER PRODUCED AND PROFIT PER 1,000 BIRDS STARTED, MARYLAND, 1947 TO 1948
(H. D. Smith, P. R. Poffenberger, and S. H. DeVault, 1949)

Range in weight per bird, lb.	No. of lots produced	Average weight per bird, lb.	Average cash cost per pound of broiler produced, cents	Average profit per 1,000 birds started, dollars
Under 2.50	13	2.37	33	15.65
2.50 to 2.749	52	2.65	30	109.24
2.75 to 2.99	131	2.88	30	122.21
3.00 to 3.247	121	3.10	28	173.63
3.25 to 3.49	79	3.34	29	174.79
3.50 to 3.749	25	3.59	29	198.78
3.75 and over	8	3.95	28	200.40

Based on the results secured by Maryland broiler producers in 1947 to 1948, it was found that for every ¼-lb. increase in average weight of broilers at selling time, cash costs of production decreased 0.6 cent per pound of broiler produced and profit increased $27.50 per 1,000 birds started. It should be observed, however, that when broilers exceeded an average of about 3 lb. in weight, the cash costs per pound of broiler produced tended to remain relatively constant, instead of decreasing, and the increase in the profit per 1,000 birds started was progressively less than from the average weight of 2.37 lb. per bird to 3.10 lb. per bird. When all costs of broiler production are considered, it seems highly probable that selling broilers at an average weight of about 3 lb. is relatively the most profitable, providing that that weight is attained in the shortest possible time and depending to some extent upon prevailing market prices for broilers of different sizes or weights.

Mortality. Disease infection and losses from mortality constitute two of the chief hazards in raising broilers and are a source of constant worry to many broiler producers. Among chickens infected with disease organisms, growth is retarded and efficiency of feed utilization is reduced. Broilers that die not only yield no returns to the broiler producer but reduce his returns because of the feed consumed prior to death. Exces-

sive mortality often results in net losses, as all too many broiler producers have unfortunately learned. The relative costliness of mortality is affected by the age at which mortality occurs, high mortality at 6 to 8 weeks being more costly than the same amount of mortality at 2 to 4 weeks.

TABLE 78. RELATIONSHIP BETWEEN MORTALITY AND PRODUCTION FACTORS, COSTS, AND RETURNS, DELAWARE, 1946
(R. O. Bausman, 1947)

	No. of broilers started per lot					
	10,000 or less			11,000 or more		
Range in mortality, per cent	0 to 8.9	9.0 to 14.9	15.0 and over	0 to 8.9	9.0 to 14.9	15.0 and over
No. of lots	15	19	26	29	18	13
No. of broilers per lot	6,709	7,815	7,472	16,830	18,518	17,766
Average mortality, per cent	5.9	12.0	21.4	6.5	11.4	24.0
Age when sold, weeks	14.2	14.4	15.0	14.4	15.9	15.4
Amount of feed per pound of broiler, lb	4.6	4.8	5.0	4.5	4.7	5.0
Costs per pound of broiler sold, cents[a]	28.4	29.8	31.7	27.3	29.8	31.6
Net returns per pound of broiler, cents[b]	5.4	5.0	2.5	7.5	5.1	0.8
Net returns per 1,000 broilers, dollars	170	145	78	228	176	38

[a] Costs include value of operator's time.
[b] Total returns less expenses, including value of operator's time.

The data in Table 78 show clearly that, as mortality increased, the age at which broilers were sold tended to be delayed, the pounds of feed consumed per pound of broiler produced increased, production costs per pound of broiler sold increased, and the net returns per pound of broiler sold and per 1,000 birds started decreased. The two groups with a range of "15.0 and over" per cent mortality gave exceedingly low net returns.

Labor Efficiency. The time and labor involved in raising broilers is influenced by the number of broilers being raised at one time, the location of the brooder houses from other centers of operation, the type of house and method of heating, laborsaving facilities available, the efficiency of the producer and hired help, and other factors. There is a vast difference between man-hours of labor per 1,000 broilers started between a farmer raising a batch of 2,000 broilers and a commercial-broiler producer, with hired help, raising 20,000 or 100,000 broilers annually.

In many sections of the country, farmers raise a few broilers each year largely with the idea of utilizing labor during the winter months when there is often relatively little else to keep them fully occupied. Although cash returns in excess of cash production costs may be quite limited, many farmers attach considerable importance to the value of manure produced for fertilizing the land. The data in Table 79 show that, as the number of lots per year and the number of broilers per lot increased, the number of hours of man labor per 1,000 broilers started decreased markedly.

TABLE 79. HOURS OF MAN LABOR USED IN RAISING RELATIVELY SMALL-SIZED LOTS OF BROILERS, WEST VIRGINIA, 1945
(J. H. Clarke, 1949)

No. of lots per year	No. of producers	No. of broilers started	Average number per lot	Labor per 1,000 broilers started		
				Cleaning houses, hr.	Feeding, tending, hr.	Total time, hr.
1	4	6,100	1,525	28.7	191.1	219.8
2	27	155,000	2,870	22.2	74.7	96.9
3	45	430,800	3,191	26.2	42.7	68.9

It is very difficult to determine the average labor cost of producing broilers for the broiler industry of the United States because of so many varying conditions existing in different parts of the country, including differences in charges for family and hired labor, the volume of broilers produced annually by different groups of producers, laborsaving facilities available, and other factors.

Size of Enterprise. In view of the rapid expansion of the broiler industry, it is natural that many farmers have become interested in the extent to which broiler production can be counted upon to supplement the returns from other farming enterprises or the extent to which broiler production will serve as the major source of farm returns. The data in Table 80 show that farmers who produced four lots during the year, each lot averaging 2,803 chicks started, or 11,212 chicks, started about eight times as many chicks as those farmers producing one lot averaging 1,420 during the year, but the former group of farmers made an average of over eleven times as much labor return per farm as the latter group of farmers, \$4,075 as compared with \$357.

Among commercial-broiler producers, the returns per man are influenced to a considerable extent by the number of broilers produced at one time. In Table 81 it is shown that, as the number of broilers produced per man increased, the production costs per pound of broiler decreased.

TABLE 80. RELATIONSHIP BETWEEN NUMBER OF LOTS PRODUCED PER YEAR AND PRODUCTION COSTS AND RETURNS, MAINE, 1944
(A. L. Perry and G. F. Dow, 1945)

Item	No. of lots per farm			
	1	2	3	4
No. of farms	76	58	28	8
No. of lots	76	116	84	32
No. of chicks started per farm	1,420	3,378	7,400	11,212
No. of chicks started per lot	1,420	1,689	2,487	2,803
Labor, daily per 1,000 birds, hours	2.3	2.3	2.2	1.7
Costs per pound of broiler, cents	25.1	24.5	25.2	21.4
Returns per pound of broiler, cents	29.1	29.1	29.2	29.0
Profit per pound of broiler, cents	4.0	4.6	4.0	7.6
Labor returns per hour, dollars	1.2	1.4	1.3	2.4
Labor returns per farm, dollars	357	924	2,023	4,075

and the net returns per pound of broiler and per 1,000 broilers produced increased.

During recent years, the tendency has been to build wider broiler houses with central-heating systems, and, in some cases, automatic mechanical feeders and automatic waterers have been installed with a view toward reducing the amount of labor required to raise broilers. These wide houses permit a manure spreader to be hauled through the center of the house, thus reducing greatly the amount of time in removing litter as compared with the customary method of cleaning out the older types of broiler houses. All these improvements in laborsaving equip-

TABLE 81. RELATIONSHIP BETWEEN BROILERS STARTED PER MAN AND COSTS AND NET RETURNS, DELAWARE, 1946
(R. O. Bausman, 1947)

Item	Broilers started per man			
	Under 8,000	8,000 to 9,999	10,000 to 11,999	Over 12,000
Average No. of broilers started per man	6,787	9,018	10,906	13,195
No. of lots	29	28	39	24
Mortality, per cent	12.0	13.7	13.1	14.1
Production costs per pound, cents[a]	30.2	29.6	29.0	28.6
Net returns per pound, cents[b]	3.9	4.2	4.8	6.0
Net returns per 1,000 broilers, dollars	118	129	148	199

[a] Include value of operator's time.
[b] Total returns less expenses, including value of operator's time.

ment make it possible for one man to care for many more broilers than formerly.

The discussion on the economics of broiler production would not be complete without reference to the marked differences among broiler producers in efficiency of management. Given chicks from the same source and the same kind of feed, houses, and facilities, no two broiler producers would secure the same net returns. In many cases the differences in labor income or net returns are due to differences in efficiency of management more than to any other factor. This is demonstrated by the results secured in a supervised broiler project in Delaware in which 40 broiler producers were supplied with chicks from the same hatch, feed from the same mill, and were given the same set of instructions in broiler management, but the differences in cash cost per pound of broiler sold between the most efficient and the least efficient producer amounted to 6.2 cents per pound of broiler sold. A high type of managerial efficiency is a most valuable asset in broiler production.

BABY-CHICK PRODUCTION

It has been pointed out previously that practically 90 per cent of all chickens raised in the United States annually are secured as baby chicks from breeder hatcheries and commercial hatcheries.

TABLE 82. PERCENTAGE DISTRIBUTION OF COMMERCIAL-HATCHERY INVESTMENT AND COSTS OF PRODUCING AND SELLING CHICKS, MARYLAND, 1937 AND 1938
(P. R. Poffenberger and S. H. DeVault, 1939)

Hatchery-investment items	Per cent of total investment	Production-cost items	Per cent of total cost
Incubators	68.8	Hatching eggs	63.7
Buildings	22.1	Selling chicks	10.4
Trucks	3.1	Hatchery overhead	10.3
Brooder and holding batteries	3.0	Labor	9.7
Land	1.7	General expenses	3.2
Miscellaneous	1.3	Miscellaneous	2.7
Total	100.0	Total	100.0

Data pertaining to each item of hatchery investment as a percentage of the total hatchery investment and each production-cost item as a percentage of the total cost of hatching and selling chicks in Maryland in 1937 and 1938 are given in Table 82.

In some modern hatcheries the capital invested in buildings is relatively more than indicated in Table 82 and the cost of incubators relatively

tively less, but in the case of most of the hatcheries in the United States probably about 90 per cent of the total investment is in incubators, buildings, and land.

The cost of hatching eggs was naturally by far the most important factor in the costs of hatching and selling chicks. Selling costs included advertising, telephone, and similar items. Hatchery-overhead cost included taxes, insurance, depreciation, and interest on the investment. General expenses included fuel, light, water, disinfectants, and similar items.

The cost of hatching eggs is decidedly the most important cost factor of incubator, as is shown in Table 83. The data in this table pertain to incubation results secured by farmers in New York State who did their own hatching. In each case, about 93 per cent of the eggs were home-produced, the balance being purchased from neighboring poultrymen.

TABLE 83. COST OF INCUBATION ON 34 POULTRY FARMS, NEW YORK, 1940 TO 1941
(L. B. Darrah, 1943)
Eggs set per farm, 23,653; chicks hatched per farm, 15,624; per cent hatch of eggs set 66.1

Costs	Cost per 100 chicks hatched	Per cent of total
Eggs	$5.25	64.2
Labor	1.26	15.4
Use of buildings and equipment	0.90	10.9
Miscellaneous	0.70	8.6
Use of automobile and truck	0.07	0.9
Total	$8.18[a]	100.0

[a] Miscellaneous returns other than chicks amounted to $0.22 per 100 chicks hatched, making the net cost of incubation $7.96 per 100 chicks hatched.

The important feature of Table 83 is the per cent of total cost contributed by the different cost factors, since the cash cost of hatching eggs and other items varies from year to year. Since the cost of eggs accounts for almost two-thirds of the total cost of incubation, it is very important to secure hatching eggs of high quality because hatchability is one of the most important factors affecting returns secured from the hatchery enterprise.

The items of cost of incubating eggs and selling chicks in Ohio during the hatching seasons of 1936 to 1948 included the following, arranged in order of importance: cost of eggs, cost of labor, sales cost, advertising cost, cost of pullorum testing and flock improvement, cost of shipping

boxes and hatchery supplies, cost of heat, light, power, and water, and miscellaneous costs.

Hatchability. Hatchery income is greatly affected by the percentage hatch of total eggs set. This is clearly shown in Table 84, the cost of hatching eggs being assumed to be 84 cents per dozen or $7 per 100.

TABLE 84. INCOME ABOVE EGG COST PER 100 EGGS SET IN RELATION TO PER CENT OF EGGS HATCHED
(H. D. Smith, P. R. Poffenberger, and S. H. DeVault, 1948)

Per cent hatched	Egg cost per 100	Gross sale at 12 cents per chick	Income above egg cost per 100 eggs
55	$7.00	$ 6.60	$−0.40
60	7.00	7.20	0.20
65	7.00	7.80	0.80
70	7.00	8.40	1.40
75	7.00	9.00	2.00
80	7.00	9.60	2.60
85	7.00	10.20	3.20

It should be noted from the data in Table 84 that for each increase of 5 per cent hatch the income increased by 60 cents per 100 eggs set.

In Maryland in 1937 and 1938 the relationship between hatchability and income, cost, and profit per 100 chicks was as follows:

Range in per cent hatchability	65.0 to 69.9	70.0 to 74.9	75.0 to 79.9	Over 79.9
Income per 100 chicks	$8.27	$8.35	$8.53	$9.22
Cost per 100 chicks	$6.79	$6.69	$6.30	$6.42
Profit per 100 chicks	$1.48	$1.66	$2.23	$2.80

The importance of securing hatching eggs of superior quality is shown by the data in Table 85.

Hatching-egg Premiums. In order to compensate hatchery-flock owners for the extra cost of producing hatching eggs, commercial-hatchery operators usually pay a premium for hatching eggs over the current market-egg price. The premium may vary from about 15 to about 40 cents a dozen, depending upon the current price of market eggs and the demand for hatching eggs in relation to available supplies. Hatchery operators should pay a reasonable premium over market-egg price for hatching eggs of high hatchability because it is a good investment. Hatchery-flock owners are thus encouraged to produce superior quality hatching eggs by keeping well-bred stock, feeding diets properly balanced

to ensure maximum hatching results, and by efficient flock management to secure the maximum production of eggs suitable for incubation.

Another good investment on the part of hatchery operators is to pay a bonus above the premium over market price based on hatching percentage. Some hatchery operators pay a bonus of ½ cent per dozen for each 1 per cent increase over 70 in hatching percentage.

TABLE 85. COST OF EGGS NECESSARY TO PRODUCE 100 CHICKS IN RELATION TO PRICE PER DOZEN AND PER CENT HATCHABILITY
(H. D. Smith, P. R. Poffenberger, and S. H. DeVault, 1948)

Price of eggs, cents per dozen	Per cent hatchability				
	65	70	75	80	85
50	$ 6.41	$ 5.95	$5.55	$5.23	$4.90
55	7.05	6.54	6.11	5.72	5.39
60	7.69	7.14	6.66	6.24	5.88
65	8.33	7.73	7.22	6.76	6.37
70	8.97	8.33	7.77	7.28	6.86
75	9.61	8.92	8.33	7.80	7.35
80	10.25	9.52	8.88	8.33	7.84
85	10.89	10.11	9.44	8.84	8.33
90	11.53	10.71	9.99	9.36	8.82

Utilizing Hatchery Capacity. To the person making a living out of the commercial-hatchery business, the total number of chicks hatched during the hatching season and each year is of tremendous importance. Capacity utilization of his incubators directly affects overhead costs per unit of production. The seasonal demand for baby chicks is important because of its relation to the seasonal price of hatching eggs. White Leghorn chicks are bought by farmers and commercial-market-egg producers primarily during the spring months, although some are purchased in January or February and in the fall months in order to have pullets for housing to replace birds as they are culled from the laying flock. The same situation also prevails with respect to general-purpose chicks bought for flock-replacement purposes. Keeping the laying house relatively full at all times is a factor involved in the efficient utilization of housing capacity. Baby chicks for broiler production are bought every month in the year.

In Fig. 253 it is shown that the average number of chicks hatched monthly from July to December during 1946 to 1948 was relatively greater than during 1930 to 1932 because during recent years the "out-

of-season" demand has increased for chicks for laying-flock replacements and for broiler production.

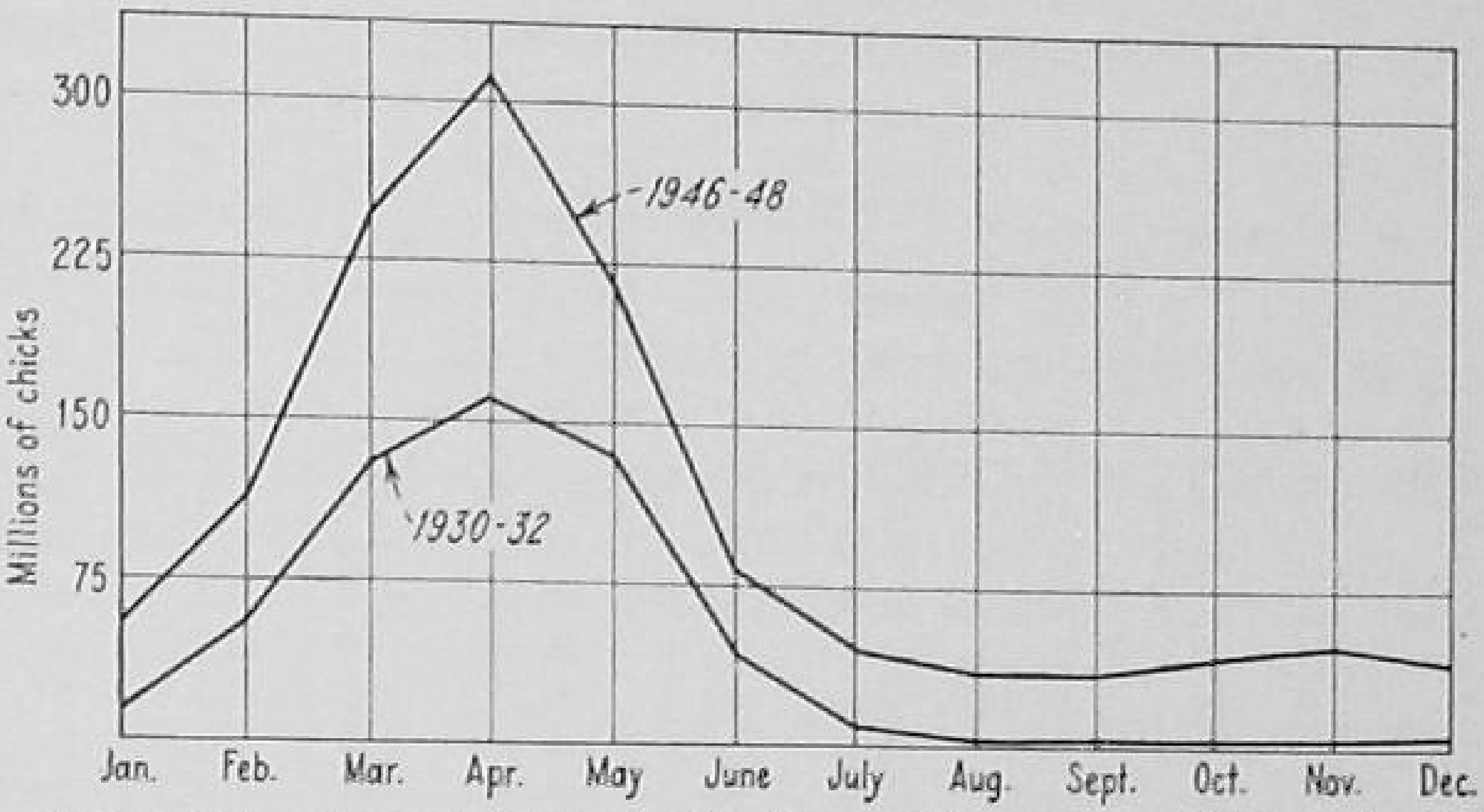

FIG. 253. Average number of chicks hatched monthly, 1930 to 1932 and 1946 to 1948. During the 3-year period 1930 to 1932, the average annual hatch was 575,049,000 chicks, whereas during the 3-year period 1946 to 1948, the average annual hatch was 1,272,492,000 chicks.

Yearly Chick Demand. Since over one-half of the chicks hatched each year are purchased during February through May, it is interesting to observe that the relative demand for chicks during that period is influenced by the gross returns from egg production over feed costs which farmers and commercial poultrymen secure during December through February, the time when most poultrymen place their orders for chicks for delivery during February through May.

Chick Prices. Herewith is given the average price in dollars per 100 chicks paid by farmers during 1946 to 1948 in each of the different regions of the United States.

North Atlantic	South Atlantic	East North Central	East South Central	West North Central	West South Central	Mountain	Pacific Coast
19.7	15.0	17.4	14.1	16.6	14.1	19.0	22.8

Poultry producers in the Pacific Coast states and in New England paid the highest average prices, whereas the lowest average prices were paid in the East and West South Central states.

The price at which hatcheries sell chicks not only varies regionally but also according to kind, as shown in Table 86. Average prices of chicks on Apr. 1, 1949, are given for a few states. Among the states mentioned, Arkansas, Delaware, and New Hampshire represent states primarily interested in the production of eggs for chicks for broiler raising. The other states are primarily interested in the production of eggs for pullet chicks as laying-flock replacements.

TABLE 86. AVERAGE PRICES RECEIVED BY HATCHERIES PER 100 CHICKS, APR. 1, 1949

State	General-purpose breeds			White Leghorns			Crossbreds		
	Straight run	Sexed pullets	Sexed cockerels	Straight run	Sexed pullets	Sexed cockerels	Straight run	Sexed pullets	Sexed cockerels
New Hampshire	$18.0	$28.5	$10.5	.....	.....	....	$17.5	$28.0	$11.0
Pennsylvania	16.5	26.5	12.5	$16.0	$33.0	$3.0	16.5	25.5	14.0
Iowa	16.0	27.0	10.0	15.5	31.0	3.2	15.5	29.0	7.9
Delaware	15.0	20.0	13.0	16.0	30.0	4.0	14.5	20.0	14.0
Tennessee	14.5	21.0	13.0	14.5	29.0	5.0	15.5	19.5	14.0
Arkansas	15.5	19.0	14.0	14.5	26.5	4.5	15.0	21.5	13.0
Utah	19.5	24.0	19.0	19.5	40.0	4.7	20.0	24.0	19.5
California	18.5	23.5	17.5	18.5	37.0	4.1	18.5	23.5	17.5

Sexing. The sexing of chicks by the vent method usually costs ½ or 1 cent per chick depending upon the number of chicks sexed at any one time. Separating the sexes of crossbred chicks produced by the sex-linked cross of Rhode Island males and Barred Plymouth Rock females used so extensively in New England can be done by the hatchery operator at very little additional expense.

During recent years, the practice of buying pullet chicks exclusively has increased as far as farmers and commercial-market-egg producers are concerned. Since White Leghorn cockerel chicks are not particularly suitable for broiler production, many of them are destroyed at hatching time. Some commercial-broiler producers buy "sexed" chicks and raise the cockerels and pullets separately. In New England and some of the adjacent states, poultry producers purchase the pullet chicks secured from the sex-linked cross of Rhode Island Red males and Barred Plymouth Rock females for laying purposes, and broiler producers purchase the cockerel chicks.

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